

# Safe Work Practices Implementation Guidance

Los Alamos National Laboratory  
Laboratory Implementation Guide LIG 300-00-01.0  
Issue Date: September 24, 1999

Nonmandatory Document

## 1.0 Introduction

### 1.1 Overview

Safe work practices are an essential part of Integrated Safety Management (ISM) at Los Alamos National Laboratory (the Laboratory) and apply to issues of environment, safety and health. Safe work practices are based upon the 5 core functions of ISM – defining the work, analyzing the hazards, developing and implementing controls, performing the work safely, and assuring performance.

This Laboratory Implementation Guidance (LIG) is a companion to LIR300-00-01, “Safe Work Practices” and LIR300-00-02, “Safe Work Practices Documentation.” The intent is to provide background information and interpretation, questions and answers, tools, models, and templates to assist in the effective implementation of safe work practices. In contrast to the LIRs which were designed to be as concise as possible, the purpose of this document is to provide greater description and explanation that will help the reader understand the intent of the LIRs. The intended audience for this LIG is anyone who needs background information to properly implement the LIRs and particularly those individuals who are responsible for identifying and evaluating hazards, developing and analyzing hazard control systems, and writing hazard control plans.

Most of the sections defined below are independent of one another. Accordingly, one can usually use the information in a particular section without needing to review the material in prior sections. The requirements contained in the LIRs are frequently repeated in this document for clarity. However, the use of the recommendations, tools, and models contained in the document is at the discretion of the reader.

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## 2.0 Background and Interpretation

### Background

The Laboratory Implementation Requirements for Safe Work Practices (SWP) are designed to provide a systematic, reasonable, graded approach to conducting work safely. These requirements are codified in LIR 300-00-01 and LIR 300-00-02 and are accessible at the following URL address:

<http://labreq.lanl.gov/hdir/labreq.html>

These requirements apply to all non-facility work<sup>1</sup>, and yes, we do mean all from typing on a keyboard to detonating high explosives. The key is to use good judgment and an appropriate level of rigor and formality for the risks posed by the hazards. The purpose of the SWP LIRs is to establish the baseline safety requirements for planning, preparing, documenting, authorizing, and executing the work. More stringent requirements may be imposed by the responsible line management or the facility in which the work is done.

Admittedly, establishing a set of requirements for the broad spectrum of work and associated hazards at the Laboratory is a difficult challenge. The approach is to focus on the fundamentals of integrated safety management (ISM) with the belief that these principles are applicable to all work at the Laboratory.

After giving the background and defining the purpose, scope, and the terms used, LIR 300-00-01 specifies the safe work responsibilities of the workers, their supervisors/line managers and ES&H subject matter experts who support the work. In keeping with the principles of ISM, the emphasis is on the workers and their line management chain. These are the individuals who must use their knowledge of the work activities to systematically identify and control the hazards associated with the work, and who must ensure that the work is done safely. Subject matter experts use their professional training and experience to support these efforts. Their knowledge of effective controls (including those stipulated by regulation or Laboratory requirement) may be essential to establishing a safe operation.

Clearly other individuals (such as Facility Managers, Project Leaders, Program Managers, etc.) have important roles and responsibilities in assuring safe operations at the Laboratory. These responsibilities are described in the ISM Description document. The focus of the SWP LIRs, however, is on those who must assure the safety of individual activities.

The specific safe work practice requirements follow the 5 core functions of ISM as shown in Figure 2.1. This process produces a “safety envelope” around the activity which is defined and documented with a Hazard Control Plan. Groups of activities are in turn surrounded by the safety envelope provided by the facility and the facility safety systems as defined in the Facility Safety Plan.

In the description that follows, the requirements of safe work practices are explained in greater detail to help the user understand both the intent and the context of the requirements. Key wording from the requirements is underlined.

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<sup>1</sup> Facility work is addressed by a separate LIR 230-03-01.1. This LIR states, “Facility Work is defined as any combination of engineering, procurement, erection, installation, assembly, disassembly, or fabrication activities involved in creating a new facility or in maintaining, altering, adding to, decontaminating, decommissioning, or rehabilitating an existing facility. This includes construction and demolition work.”

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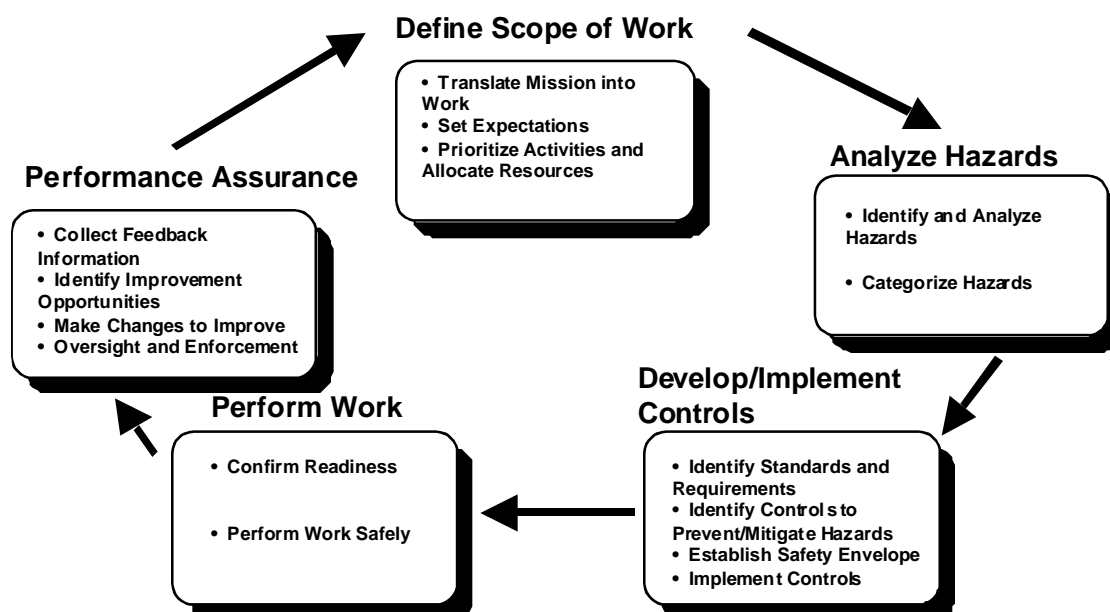


Fig. 2.1 This figure illustrates the 5 core functions of the integrated safety management program that the Laboratory has adopted to ensure that work is performed safely.

## Define the Work

Both what the work is and how it will be done must be defined with sufficient detail to enable the hazards and the situations or circumstances in which they could cause harm to be identified and evaluated. Basically, you can't foresee and control the hazards unless you know what you are going to do and how you are going to do it.

The degree of planning required could vary enormously depending on what the work is and how similar it is to work for which a safe practice has already been established. The time required can range from a few seconds to many months. It is the responsibility of both the workers and their supervisors<sup>2</sup> to use good judgment to determine when the planning is adequate.

There is no universally applicable approach to planning the work. However, as a general guide it is important to break the work down into reasonable components. Many of these components may be operations where an operation is defined as a set of activities or actions with a related purpose that are typically performed in a specific location (e.g. a particular room), in sequence (or close together in time), and may be repeated (with minor variations) on various projects. Examples of operations are: operating an electron microscope, cleaning a vacuum evaporator, detonating a high explosive sample, or replacing the toner cartridge in a copying machine.

<sup>2</sup> A supervisor is defined as any individual with the authority and responsibility to direct and authorize the activities of workers, such as Team Leaders, Group Leaders, and Division Directors. Line managers are a subset of supervisors who are formally designated managers and who are responsible for Laboratory workers' terms and conditions of employment, such as Group Leaders or Division Directors. All University of California and subcontractor employees and managers, supervising or performing work and all visitors are in a **safety-responsible line-management chain**. Throughout this line management chain, safety is integral to decisions relating to the performance of work, including resource allocation, planning, scheduling, and coordination.

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Once an operation is defined, it is usually straightforward to identify the hazards associated with the operation. However, until the operation is further broken down into its parts, actions, or activities, it may be very difficult to foresee how the hazards may cause harm.

Again, there is no universal guide, but useful questions to ask are: What do I do first, second, third? What is connected to this? Where or from whom do I receive this? Many, if not most, accidents occur from circumstances arising at this level of detail, so it is important to plan the work with sufficient detail to reveal these circumstances. Other questions that may need answering are: Who is going to do the work? When is it going to be done? Where is it going to be done?

Frequently the work has been clearly defined either by you or others previously and appropriate effective controls for the hazards have been established. In this case redefining the work is only necessary to the degree that changes may introduce new hazards.

The documentation required for defining the work depends entirely on the hazards identified, the risks they pose, and the controls needed to mitigate these risks, and may range from none to detailed step-by-step descriptions. These documentation requirements are specified in LIR 300-00-02.

## Identify and Evaluate Hazards

Here again it is the workers and their supervisors who are responsible for identifying and evaluating the hazards associated with the work. They are required to use their knowledge of the work activities to systematically identify the hazards associated with the work and to identify all the conditions that could cause injury or harm to workers, the public, or the environment, or damage to or loss of property.

This is where involving a knowledgeable peer or peers and ES&H subject matter experts may be desirable or essential. Again, the need for involvement of others is graded. If the hazard manifestations are subtle, you are not fully confident that you have identified them all, or the risks are high, engaging others to provide complementary perspectives and knowledge is essential. Taking a conservative approach is advisable. It is better to get some help than to overlook a potentially dangerous situation.

As mentioned before, it is usually much easier to identify and quantify the hazards (e.g., electrical - 1000V at 1A, chemical - 2 liters of benzene, radiation - 0.5 Curie of tritium, etc.) than it is to foresee the conditions, circumstances, or manifestations in which the hazard could cause harm (e.g., the sample containers are mixed up, toxic gas flows in the unexpected direction, electrical power was locked out but not physically disconnected, etc.).

Each of the manifestations for each of the hazards has a certain risk associated with it. The objective is to control each of these risks to an acceptable level, where in the end "acceptable" is a judgment by the responsible supervisor or line manager based upon reference to social standards.

To get to this point, the risk associated with each identified hazard manifestation needs to be evaluated. This sounds like an onerous task, but it need not be. First of all, you simply need to make a judgment whether the uncontrolled risk under reasonable circumstances is acceptable or not.

This judgment is based on both the likelihood of a particular manifestation and the consequence or severity of harm if it does occur. As shown notionally in Fig. 2.2, a risk of severe consequence may be acceptable if the likelihood is sufficiently low. Similarly the risk of a highly likely event may be acceptable if the harm is sufficiently low. Conversely, if a worker could be severely injured or killed and the uncontrolled likelihood of this happening is significant (such as reaching barehanded into an energized, high-power electrical system) the risk is unacceptable and controls are clearly needed. Alternatively, if the harm is modest but is highly likely to occur (such as repetitive motion strains from long-duration key boarding with poor ergonomics) the risk is unacceptable and effective controls are clearly needed.

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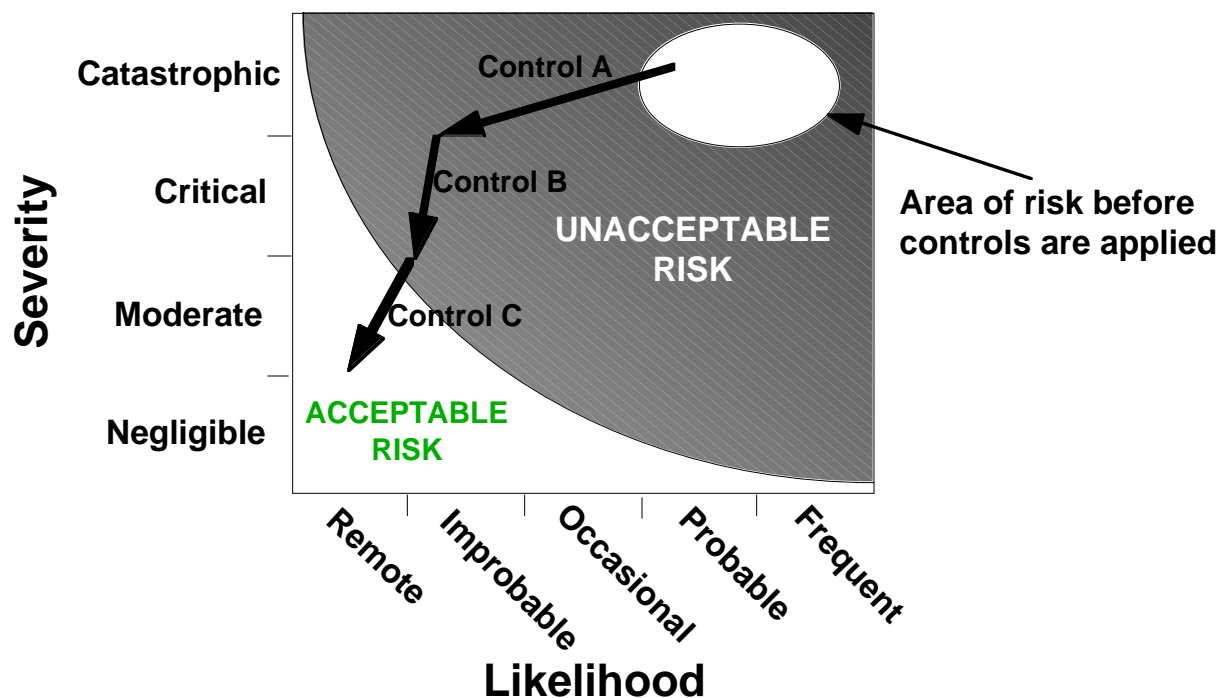


Fig. 2.2 The concept of controlling the risk of an operation to an acceptable level is shown notionally in this figure. The risk of particular hazard manifestation is characterized both by consequence and the probability of it occurring. In this illustration a set of controls A, B, & C are imposed to bring the risk of the hazard to an acceptable level.

A quantitative or detailed analysis of risk is not required and in most cases is not warranted. Instead a reasonable estimate needs to be made which is sufficient to categorize the risk as high, medium, low, or minimal. These designations serve as a guide to the rigor required to develop appropriate controls.

It may take only a minute or two to evaluate many of the hazard manifestations you foresee. These, however, are minutes well spent. You are unlikely to prevent an accident that you haven't thought about, and the investment of this effort could save you and your family a lot of suffering. Identifying and evaluating hazards is a skill that you should develop to the degree appropriate for the hazards you confront or for which you must develop controls.

As before, the documentation required for identifying and evaluating the hazards depends on what those hazards are and is addressed in the next section.

For most of the work you undertake on a daily basis, this task of identifying and evaluating the hazards has been done previously by you or others. It is however essential for you to know what hazards associated with your work pose significant risk and what controls have been established to mitigate those risks. Similarly, it is essential for you to assess whether there are any new or increased hazards associated with the work that have not been appropriately evaluated. This ranges from changing the quantity of high explosive you may be testing to considering the fact that it snowed last night before you start the vehicle.

## Develop and Implement Controls.

Once you have identified the hazard manifestations that may pose unacceptable risk, controls must be defined (or developed) and implemented, as needed, to reduce the risks associated with the work to an acceptable level. As indicated in Fig. 2.2, one or more controls may be needed to mitigate the risk associated with the hazard to an acceptable level. These controls may change the likelihood and/or the severity of an occurrence.

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## *Institutional and Facility Requirements*

Effective controls for many hazards have been established by long experience and refinement and take the form of government regulations and/or Laboratory requirements. If they apply, you must adhere to them. Here in particular, ES&H subject matter experts can be of great assistance, as they are familiar with these regulations and requirements and can determine how or if they apply to your work. In addition you can access the documents that specify these regulations and requirements by using the ES&H key-word search engine on the WEB at <http://labreq.lanl.gov/htmls/opsquery.html>.

For most work at the Laboratory, the facility in which the work is housed and the restrictions on the work that can be done in that facility provide a safety envelope which serves to protect the public, other workers and residents, and contributes to the safety of the work itself. The facility-related operating requirements must be observed and adhered to for all operations in the facility. Similarly, these operating requirements must be taken into account when developing controls for the hazards associated with the work.

## *Hazard Control Hierarchy*

The hierarchy of effectiveness for controls which goes as follows.

- 1) eliminate the hazard if you can by modifying the work
- 2) substitute with something that serves the function adequately but is less hazardous
- 3) establish engineered controls, which provide a reliable, physical isolation from the hazard
- 4) establish administrative controls, which are rules, procedures, or indicators such as signs that define safe actions for workers or others who might be impacted by the work.
- 5) provide personal protective equipment

These controls must be complemented and supported by identifying the knowledge, skills, and abilities required of the workers involved in the work to perform the work safely. This of course implies that appropriate training is needed. This training might be provided by an instructor in the classroom or a mentor on the job. The key is to ensure the worker actually has the skill required not just the knowledge.

## *System Failure Analysis*

Once a hazard control system has been defined or developed it is necessary to analyze, with a rigor commensurate with the risk, potential failures of controls, equipment, utilities, facility systems, procedures, or human factors; estimate the risk of such failures; and consider enhancements and/or alternatives as needed. The rigor of this analysis should be graded appropriately for the work and the hazards it presents. For bringing up a new accelerator, it may be a lengthy process using formal system-failure-analysis methodology. For performing a chemical reaction in a hood, it may be recognizing the hazard associated with a power failure and the development of an appropriate action plan for this contingency.

## *The Risk Matrix*

The matrix below is to be used to determine the level of risk based upon both the severity and likelihood of an occurrence. As can be seen, even catastrophic consequences can be of low risk if the likelihood of occurrence is sufficiently small. Conversely, the risk of even minor injury is considered high if the likelihood of occurrence is sufficiently high.

To ensure that appropriate and effective controls have been defined or developed a graded level of review is required as determined by the initial risk<sup>3</sup> associated with the hazards. If the initial risk is high, concurrence of ES&H subject matter expert(s) and independent peer(s) is required. For example, if you are setting up an experiment to do chemical vapor deposition (CVD) using arsine (extraordinarily toxic) gas, getting a toxic-gas-handling subject-matter expert

<sup>3</sup> Initial risk is the risk you are confronted with when you begin the process of defining, developing, and implementing controls. The intrinsic risk associated with the hazard may be largely controlled by well-established means. In this case, the initial risk may be substantially lower than the intrinsic or unmitigated risk.

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and one or more peers familiar with CVD systems and their hazards to review the control system would be appropriate, and their concurrence would be required to have the work authorized (see the section on Authorization below.)

Similarly, if the initial risk is medium, consultation with ES&H subject matter expert(s) and/or independent peer(s) is required and is a sensible check on the hazard control system. However, for this level of risk a formal concurrence is not required.

For those initial risks, which are low or minimal, no review is required, but it may be a prudent action nevertheless depending on the work and the nature of the hazards.

<b>Severity</b>	<b>Likelihood</b>				
	<b>Frequent</b> occurs often -to- likely to occur, reasonably expected	<b>Probable</b> likely to occur, reasonably expected -to- irregular occurrence, infrequent	<b>Occasional</b> irregular occurrence, infrequent -to- slight chance of occurrence	<b>Improbable</b> slight chance of occurrence -to- highly unlikely to occur	<b>Remote</b> highly unlikely to occur -to- extremely unlikely to occur
<b>Catastrophic</b> death, severe injury/occupational illness, severe environmental harm, or severe property damage	<b>High</b>	<b>High</b>	<b>High</b>	<b>Medium</b>	<b>Low</b>
<b>Critical</b> major injury/chronic impairment or occupational illness, major environmental harm, or major property damage	<b>High</b>	<b>High</b>	<b>Medium</b>	<b>Low</b>	<b>Minimal</b>
<b>Moderate</b> minor injury/temporary impairment or occupational illness, minor environmental harm, or minor property damage	<b>High</b>	<b>Medium</b>	<b>Low</b>	<b>Minimal</b>	<b>Minimal</b>
<b>Negligible</b> less than minor injury or occupational illness, less than minor environmental harm, or less than minor property damage	<b>Low</b>	<b>Minimal</b>	<b>Minimal</b>	<b>Minimal</b>	<b>Minimal</b>

## Documentation

Documenting the hazard control system promotes systematic thinking about the work, the hazards and the circumstances in which the hazards may be manifested, the risk posed by these hazards, and the controls necessary to bring these risks to an acceptable level. In addition, this documentation provides the means to bring the hazards to others attention and to instruct them in the controls and how to use these controls to mitigate the hazards.

The requirement is that when new controls are developed or existing controls are modified, you must document the hazards identified, the risks posed, and the controls established

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in a hazard control plan. The logic of this requirement is that if you identified a hazard and/or its manifestation for which established controls are inadequate or nonexistent, and you have to develop one or more controls to bring the risk to an acceptable level, you need to write down the problem and its solution. This document is called a “hazard control plan.” It can be as simple or as complex as needed to effectively communicate: what the hazard is and how it might occur, the level of risk posed (which determines the rigor of review required), and the hazard control system established to mitigate the risk to an acceptable (and authorizable) level. The latter should also include the skills, knowledge, and abilities of the workers needed to deal with the hazards and the control system effectively. The detailed requirements are contained in LIR 300-00-02.

The hazards associated with much of the work at the Laboratory have been effectively controlled by the manufacturer of the equipment or by previous development of a hazard control system. A good example is the operation of a scanning electron microscope. Although this instrument has a number of significant, intrinsic hazards (high voltage, x-ray radiation, vacuum system, etc.), effective engineered controls have been built into the system by the manufacturer, and if the instrument is used in accordance with the operating manual, no additional documentation is required. Comparable operations can be documented with a common hazard control plan, such as safe use of an x-ray diffractometer. If writing a custom hazard control plan does not add value over existing documentation in communicating how to effectively deal with the hazards of the work, additional documentation is not required. However, frequently in research work, equipment is modified or used outside of its normal operating parameters. These changes or operating conditions definitely require the appropriate documentation to communicate the modified hazards and the additional (or modified) controls that may be needed to mitigate them.

## Authorization

Authorization is the acceptance of the residual risk by the appropriate level of supervision and constitutes their approval of the adequacy of the control system and workers’ knowledge, skills, and abilities to perform the work safely. Accordingly, authorization has two parts: authorization of the work and authorization of the workers.

Authorization of the work is based on the residual risk which includes the reliability and certainty of the controls to maintain an acceptable level of risk, the consequences and likelihood of control failure, and the adequacy of the controls to meet institutional, facility, and activity requirements. The same matrix that was used to determine the initial risk is applied to determine the residual risk once the controls have been implemented. The acceptability of the residual risk is determined by the authorizing line manager or supervisor based on the advice and judgment of the individuals who developed and reviewed the hazard control system.

It is the supervisor’s responsibility to understand the work and associated hazard control system sufficiently to judge the acceptability of the residual risk prior to authorizing that work and to ensure that the hazard control system for the activity is in place and verified to be functional before authorizing the work. The initial authorization for an activity constitutes the certification of readiness of the work to be performed.

The authorization level escalates with the level of residual risk. If the residual risk is minimal the immediate supervisor may authorize the work. However if the residual risk is low a Group Leader (or equivalent) must authorize the work, and in those circumstances in which the residual risk can only be brought to the medium level, a Division Director (or equivalent) must determine whether the value and importance of the work outweigh the risk. If the risk associated with the work can not be reduced below the high level, the work must not be authorized or performed. If the supervisor or line manager is unsure about the residual risk involved with the work, he/she should defer to a higher management level for authorization of the work.

If reducing the risks to an acceptable and authorizable level required the development or modification of controls, the authorization must be in writing. This can be easily handled with

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an approval signature by the authorizing authority on the hazard control plan. Work authorizations are required to be reviewed and renewed periodically, commensurate with the level of risk. The frequency of this review and renewal must be stipulated in the hazard control plan. For operations with minimal residual risk and with stable, well-understood, and reliable controls a renewal every 3 years might be appropriate. Conversely, for an operation with low or medium residual risk and greater uncertainty in the controls, review and renewal every 3 months might be appropriate.

Authorization of workers is granted when their knowledge, skills, and abilities are sufficient to perform the work safely. This process must be exercised individually and distinctly from authorizing the work. The individual worker might not have been involved in developing or establishing the hazard control system for the work. Nevertheless, they need to understand what the hazards are and have the knowledge, skills, and abilities to effectively utilize the controls and to perform the work safely. Frequently this requires specific training which may need periodic refreshment to be effective.

Authorization of workers engaged in low or medium residual risk work is granted in writing by their line manager. Authorization of workers engaged in minimal residual risk work can be granted by their immediate supervisor. For minimal residual risk work, documentation of the authorization is not required but may be appropriate. These authorizations must be reviewed and renewed periodically, commensurate with the level of risk, but at least annually. For routine work of minimal hazard, this can be easily accomplished in conjunction with the annual discussion of performance objectives. However, for more hazardous work, renewal and reauthorization should be stimulated by any significant change in hazard or need to refresh safety-critical skills. Although the appropriate level of supervision grants the workers authorization, it is the responsibility of the worker to obtain and renew authorizations to perform the work. This entails an appropriate vigilance on the part of the worker to identify changes in the hazards associated with the work and to seek the appropriate authorization. Similarly the supervisor is responsible for ensuring that workers have the knowledge, skills, and abilities needed to perform the work safely before authorizing them.

## Performing the work safely

Performing the work safely requires appropriate preparation and attention to detail. In preparing, the worker should perform a self-readiness check, commensurate with the level of risk, before each day's activities to verify that work conditions have not changed, that controls are in place and functional, and that authorizations are current. For many operations this self-readiness check may need only a few seconds. Examples include verifying that your hood is operating before opening the chemical containers or checking that your chair is still set at an ergonomic height before beginning to type. For other operations, such as disassembly of a nuclear weapon secondary, the self-readiness check might involve a formal, written checklist with independent verification.

In performing the work, the worker should use the established hazard control system. Significant thought and care goes into the development of an effective hazard control system. Ignoring it or making ad hoc modifications can be inherently dangerous.

The success of the entire process of safe work practice hinges on how the daily activities are done. It starts with defining the day's (or even the next hour's) work. Frequently this is the same kind of work that has been performed many times before. Nevertheless, pausing to assess whether there are any new, different, or increased hazards can prevent many accidents and injuries. Determining whether you are (or are still) authorized to do the work is a second check. Before you begin the work, you need to verify that the control system is in place and working. This includes verifying that engineering controls are functioning, donning personal protective equipment as required, and following established procedures. **The most important ingredient, however, is your commitment and engagement in performing the work safely.**

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## Performance Assurance

Feedback information on the adequacy of controls and identification of opportunities for improvement are necessary for maintaining safe operations. This involves periodically reviewing the work, commensurate with the risk, to evaluate whether changes in the work scope, hazards, or other conditions warrant revision of the hazard control system. Similarly you should periodically re-evaluate the effectiveness of the controls and use lessons learned from control failures, near misses, or accidents to improve the control system. In doing this, you should develop and use a change-control process, with rigor appropriate to the risk, to document changes in the hazard control system and to inform workers and other impacted personnel of those changes.

## Summary

The safe work practice process is summarized in the flow diagram of Figure 2.3 below.

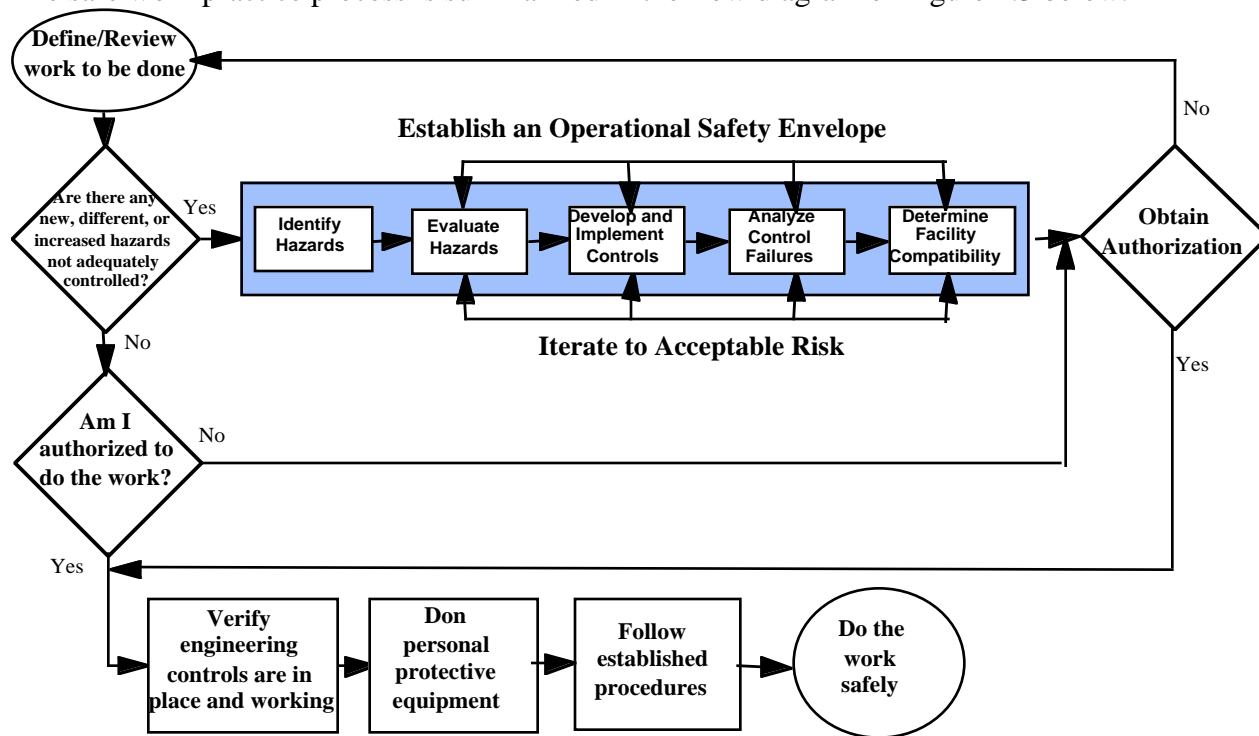


Fig. 2.3 This figure illustrates the activity flow that must be conducted in order to ensure that work is performed safely.

Safe work practices are an essential part of Integrated Safety Management (ISM) at the Laboratory. Safe work practices require defining the work; establishing, documenting, and maintaining an effective hazard control system within which the work is performed; and authorizing both the defined work and the workers to perform the work. Integrating safe work practices with work activities requires workers and their line managers/supervisors to use a systematic, graded approach and good judgment in applying their knowledge of the work to identifying hazards and controls so that the work can be performed safely.

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## 3.0 Questions and Answers

### **Do I need to implement Safe Work Practices for everything I do? Do I need to have a Hazard Control Plan for everything, and if not, how do I show that I have implemented the processes for things without one?**

The short answer is yes, unless facility work control applies, or you have a variance to use another equivalent system. With these exceptions, you need to implement Safe Work Practices for all Laboratory work. However, you certainly do not need a Hazard Control Plan for everything. A Hazard Control Plan is required only when Laboratory-implemented controls are needed to mitigate the risk to acceptable level or when established documentation, such as the owners manual, is inadequate to communicate the hazards and controls to the worker.

Remember, the purpose of the Hazard Control Plan is to communicate to workers and document for them what they need to know about the hazards and associated controls for an activity when they have no other documented source for this information.

For work with low or higher residual risk, you show that you have implemented the process by documenting the worker authorization. If controls are required to mitigate the risk to an acceptable level, you should be able to show the documentation that the worker would use to understand the hazards and the controls. This could be a Hazard Control Plan, an owner's manual, or other established documentation that provides the necessary information. If there are no hazards that require understanding or controls, no documentation is required.

### **Why do we have separate systems for facility work control and safe work practices?**

The separate systems for Facility Management Work Control and Safe Work Practices are partly an historical artifact. The Facility Management Work Control system was developed in response to a serious accident related to facility work. This both preceded and emphasized the need for an R&D work control system that became known as Safe Work Practices. The urgency of getting Facility Work Control implemented at the time precluded redesigning the system to achieve better consistency with R&D work. The management of construction, maintenance and craftwork does have real distinctions from the management of R&D work. However, both types of work must meet the same technical safety requirements, for example the electrical safety LIR or the Worker Health and Safety LPR. We are committed to an ongoing review and improvement of both R&D and facility work control LIRs.

### **What are examples of the appropriate level of rigor to apply for identification and evaluation of hazards for each risk level (particularly low and minimal)?**

The short answer is whatever rigor the cognizant manager judges is necessary to ensure that the hazards have been controlled to an acceptable level. There are two web-based tools available to help identify and evaluate hazards. The first is the LANL Hazard Identification Tool, which is available at the following URL address:

<http://hazardid.lanl.gov> .

Based on answers to a nested set of questions, this tool calculates a "Hazard Rating" of 0, 1, 2, or 3. This rating relates to the potential severity (with 3 being the highest) of hazards in an operation before quantities, likelihood, or particular circumstances are taken into account. For example, if the operation involves known carcinogens, the tool will return a Hazard Rating of at least 2. This means you should consider a "Critical" severity in the risk matrix of the Safe Work Practices LIR 300-00-01. However, if only minute quantities of the carcinogen are being used, the severity might be less.

The second is the ESH ID Review Process, which is available at the following URL address:

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<http://www.eshid.lanl.gov> .

The review process is designed to provide uniformity in Operational Risk Management across facility management units (FMUs), programs, and processes throughout the Laboratory. It provides a formal, systematic, and documented approach for risk identification and hazard management and provides safety, health, and environmental review of operations of Laboratory facilities.

In evaluating hazards, judgement is required based on the real situation and reasonable scenarios by which the hazards identified might cause harm. As a conservative guide, if you can think of a plausible scenario in which significant worker or environmental injury could occur, start with a rigor appropriate for high risk and work down if further investigation so warrants. Conversely, if careful consideration identifies no plausible scenario in which significant worker or environmental injury could occur, use a rigor appropriate for low or minimal initial risk.

## **Can you clarify what you consider as part of initial risk determination?**

The key elements of initial risk determination are effective hazard identification and hazard evaluation. Hazard identification is the determination of the material, agent, or energy source that can cause harm. Hazard evaluation is the process of determining the potential severity and likelihood of conceivable accidents or exposures to these hazards. The focus should be on identifying what controls are needed rather than on giving a particular label to the risk of an activity. Accordingly, the risk determination is qualitative and is to be used as a guide to the rigor to be applied to the subsequent review and authorization process. Remember, if you are in doubt about the general level of risk, you are required to use the rigor appropriate for a higher level of risk.

## **Can I have more guidance on what the likelihood axis on the risk determination matrix means?**

The likelihood axis is widely used for applying a graded approach to managing risk. You need to take into account both the severity of potential consequence and the likelihood of that consequence to have a reasonable approach to selecting a control that mitigates the risk to an acceptable level. For example, if you cut your finger every time you use a particular tool, something is wrong, and you need to develop a control that makes this much less likely. If a control can be applied that reduces the likelihood of the finger cut to 1/10,000 uses, a significantly more complicated or costly control that reduces the likelihood to 1/100,000 uses may not be warranted because other risks are probably greater and more in need of control. Conversely, if the likelihood of dying in the activity is 1/10,000, the risk is unacceptable, and a control must be found that eliminates or drastically reduces this risk.

In considering likelihood, focus first on achieving acceptable risk each time you conduct the activity and then look at the number of times the activity will be conducted. If the likelihood is stochastic, the total likelihood is equal to the number of opportunities times the likelihood at each opportunity. The best general guidance is to ensure your controls make the risk acceptable at each opportunity and enhance them as is prudent for the number of opportunities or exposures that will be experienced over the duration of the activity. A good example of this principle is managing radiation exposure. First you need to ensure that the dose from a single exposure is completely acceptable. Then, if an individual is going to be exposed repetitively, the controls should be designed to ensure that the cumulative dose is also completely acceptable.

## **How do I make risk determinations for R&D operations that have never been done before?**

You make such risk determinations by careful judgement of what might happen based on the known or anticipated hazards. To do this, you use known science to anticipate a worst-case scenario. For example, if you are trying to synthesize an entirely new high explosive, you can

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calculate the energy in all of the bonds and use that as a worst-case estimate of the damage that could be done if the material was inadvertently detonated. If you have knowledge that lets you reduce this risk in severity or likelihood, you can take that into account in determining risk. Otherwise, you should control for the worst-case scenario. In this process it is important to team with subject matter experts that have the greatest relevant knowledge to the work you are going to do.

## **How can I ensure that I am considering hazards that I don't know much about? There are some things that I don't understand well enough to even ask about.**

The best answer to, "How can I know what I don't know?" is to get some help. If you are in doubt about your own knowledge relevant to the hazards associated with an activity, seek subject-matter expertise in each area until you have a feeling of confidence. Then, have the control system reviewed by both technical peers and subject-matter experts, as appropriate to the hazards that are being controlled. Again, if you are in doubt about the general level of risk, always use the rigor appropriate for a higher level of risk.

## **How can I implement Safe Work Practices in an R&D setting in which operations, hazards, controls, etc. change significantly from one day to the next?**

We all are called upon to work safely every day, no excuses. Hazards are probably greater when the work changes from one day to the next, and extra care is probably called for in these cases. This is an instance where the statement in the ES&H safety policy that "we will never compromise safety for operational needs" is hard to meet but even more important.

The focus should be on defining a "safe operating envelope" for the R&D activity. This envelope is a domain that defines the hazards that are likely to be encountered, including the materials that will be used, the energy sources, etc. Once plausible worst-case scenarios are considered within this domain and adequately controlled, you can have significant flexibility in what you do as long as you maintain your activity within the limitations defined by the controls. This might include quantities of materials to be used, voltages not to be exceeded, etc.

## **What are the risks associated with driving government vehicles and doing standard administrative work?**

The risks of driving a vehicle are substantial, as evidenced by the injuries and deaths that occur every year. However, over the past century, our society has developed a set of controls to mitigate these risks. Further, the Laboratory insists on the use of these controls, including being a licensed driver, using seat belts, and obeying the speed limit. With these controls in place, the work, having been thoroughly reviewed, is authorized at the institutional level. However, each worker should be authorized to do this work (i.e., drive a government vehicle) based on his/her having the knowledge and skills to use the controls and the commitment to actually use them. Rather than debating whether the residual risk is medium, low, or minimal, we recommend that managers establish a worker authorization process in their organizations whereby proper licensing is checked and documented annually and these drivers are reminded of Laboratory requirements for safe driving.

The answer for standard administrative work, such as keyboarding and copying is similar. This type of work has real hazards as evidenced by the large number of ergonomic injuries we experience. Again, the controls for this work usually have been defined at an institutional level, and with these controls, the work is authorized. Each worker should be authorized to do this work based on his/her having the knowledge and skills to use the controls and the commitment to actually use them. The residual risk of this work with the controls effectively used is usually minimal, and so, documenting the authorization is not required.

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## **If I pick someone as a Subject Matter Expert that isn't in an ES&H position won't others second-guess me?**

Focus on picking people that can really give you advise and review that helps ensure the effectiveness of the control system. It is your well being and that of your associates that is on the front line. If someone suggests additional review, consider it in the spirit in which it is usually intended – helping to improve safety. In the end it is the person who authorizes the work to determine whether the people selected to review the control system provide an adequate breadth and depth of review.

## **What is going to happen to me if I have an accident that I didn't foresee in my hazard identification and evaluation?**

You probably are going to get hurt or have your co-workers hurt or your work destroyed or delayed. So it pays to do the hazard identification and evaluation well. Here again, teaming with subject matter experts can have a big benefit. If you did a demonstrably conscientious job in doing the hazard identification and evaluation and had the appropriate reviews, no disciplinary action should be taken. You will be obligated to take appropriate actions to ensure that a similar accident does not happen again and to help disseminate the lessons learned. Conversely, if you did a sloppy job in the hazard identification and evaluation; failed to get appropriate review; or ignored procedures, controls, or requirements, you may be subject to disciplinary action.

## **What happens if I have an accident that I did foresee but still happens? Do I have liability issues to worry about?**

This is a difficult question to answer in abstract terms. It will depend heavily on the circumstances. However if you were acting in the course and scope of your employment and you did a reasonable and conscientious job, the Laboratory will defend you in any civil action that might be brought as a result of the accident.

## **What kinds of management systems are needed for safe work practices?**

Good management systems are those that provide a systematic approach to ensure that appropriate rigor is applied to hazard identification, evaluation, and control for all of the work that goes on in the organization and that the people who do the work understand and use the controls effectively. Elements of a good system are

- a complete inventory of all activities in the organization;
- a methodical approach to identify the hazards and evaluate the risks associated with each activity;
- a method to engage the appropriate technical and ES&H subject matter expertise to evaluate the control systems when needed;
- hazard control plans that communicate effectively to the workers what the hazards are and how they have been controlled;
- a means of identifying every worker engaged in an activity and ensuring that these workers have the knowledge, skills, and abilities needed to understand the hazards and use the control systems effectively;
- a means of establishing and communicating the authorization status of each activity and each worker to all of the workers;
- a communication system that is well understood, easy to use, and effective, and that incorporates an appropriate change control mechanism;
- plans and methods to periodically review and improve the safety and environmental soundness of all activities in the organization; and
- most importantly, direct and personal involvement of the management in the process.

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## **Do I need to document how I came up with my risk determination, or is gut instinct acceptable in coming up with a determination? How do you defend gut instinct, if that is acceptable, and I have an accident?**

If the consequences of a credible accident are serious, you should either document the basis for your risk determination or use the process prescribed for high initial risk. Gut instinct is not good enough when people's lives are at stake. The graded approach defined in Safe Work Practices allows for an appropriate level of rigor after careful consideration. If you are in doubt about the general level of risk, you are required to use the rigor appropriate for a higher level of risk.

## **Do I have to maintain documentation of the specific hazard identification and evaluation that I did?**

LIR 300-00-02.1 states, *"For activities in which the hazards could potentially pose high or medium initial risk, documentation of the hazard evaluation performed to consider accident scenarios and determine initial risk is required and must be retained. Similarly analyses performed to select or design controls or to determine the effectiveness and reliability of these controls must be retained. These records provide a foundation for modifying or improving the control system and a valuable reference for future users of the controls."*

## **For now I can combine existing documents for a Hazard Control Plan, but where is it required that I must combine them all together in the future?**

LIR 300-00-02 states, *"The hazard control plan may be a combination of documents, which contain the essential information, or may reference other documents, without reproducing them. When other documents are referenced, the source or method of access for the documents must be specified."* You are not required to integrate them in the future. However, at each of the specified review cycles of the Hazard Control Plan, you should assess whether the documents are serving the function of effectively communicating the hazards and controls to the workers. If not, the document(s) should be revised until they do so.

## **Which safety documents are going away and being replaced by HCP's?**

LIR 300-00-02 states, *"Current hazard control documentation at the activity level (for example, standard or safe operating procedures, special or safe work permits, experimental plans, and health and safety plans) that substantially meets the requirements contained in this LIR may be used as is until the next review date, at which time they must be brought into conformance with these requirements."* The objective is to simplify the documentation for the benefit of the worker. In some cases, such as standard or safe operating procedures that effectively communicate the hazards and associated controls to the worker, the only change required may be no more than a new cover sheet. In other cases, either because of the inadequacy of the existing documents or because of their complexity, major revision and replacement may be required.

## **Where do I get information such as checklists, FMEA tables, etc.?**

Your ES&H point of contact can provide reference material and valuable advice. Other good sources are the Safe Work Practices Implementation course manual, the Hazard Identification Tool, available at the following URL address, <http://hazardid.lanl.gov> and the ESH ID Review Process, available at <http://www.eshid.lanl.gov>.

## **Where can I find all the things I'm required to know to do this (i.e., regulations, LIRs, or programs that apply to me)?**

The Laboratory requirement documents, including LIRs, are all available at the following URL address. <http://labreq.lanl.gov/hdir/labreq.html>

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**How can I find out the system other divisions use to implement Safe Work Practices when I have to do work on projects in those divisions? How do I keep from having people fall through the cracks when they do this?**

For the details, you need to ask the people you will be working with in the other Divisions.

However, the fundamentals are the same in all Divisions. The organization responsible for the work or activity must perform the hazard identification and evaluation for the activity and develop or ensure that the controls are adequate for the work to be done safely. In this process, they must define the training, knowledge, skills, and abilities needed by all of the workers engaged in the activity. If a worker is not qualified, based on the training, knowledge, skills, and abilities, he/she can be precluded from working on the activity. The worker also must be authorized for the work by his/her supervisor or line manager, based on the residual risk associated with the work, before he/she engage in the work. In summary, three conditions must be met before the work proceeds.

1. The worker must be confident that the work is safe to do.
2. The cognizant person in the organization responsible for the work must be confident that the worker is qualified to do the work.
3. The supervisor or line manager of the worker must be satisfied both that the hazards are adequately controlled and that the worker has the necessary training, knowledge, skills, and abilities to do the job safely in order to authorize the worker.

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## 4.0 Definition of Work – Activity Inventory

One of the required components of Safe Work Practices Documentation is an Inventory of Activities in the organization. Below is an example inventory based on activity location. The content of this example exceeds the requirements of LIR 300-00-02, which requires, “at a minimum, all activities for which the initial risk is high or medium and all activities for which the residual risk is medium or low. For each such activity, the inventory must record a distinct name or description to identify the work, sufficient information to determine where the work is or will be performed, and the authorization status of the work.” The additional information in the example below is valuable for management review and analysis.

ACTIVITY#	ACTIVITY TITLE	POC NAME	POC PHONE	INITIAL RISK LEVEL	RESIDUAL RISK LEVEL	HCP REQ ?	AUTH DATE	REV
ORG-TA-BLDG-RM-ACTIVITY								
8Z09-3-29-2112-1	Flux Growth of Actinide Single Crystals	Mat Scientist	6-2342	High	Low	Yes	06/25/98	2 yrs.
8Z09-3-32-104-1	Miscellaneous Assembly	I. A. M. Goodwith hands	6-0843	Low	Low	No	07/22/98	2 yrs.
8Z09-3-32-104-2	Machining (Staff)	P. R. Ecision	6-0845	Medium	Low	Yes	07/22/98	2 yrs.
8Z09-3-32-109-2	Pressure Test/Crane Hoist	H. I. Pressure	6-6867	High	Low	Yes	Inactive	?.
8Z13-3-32-110-1	Optical Shadow Graph	S. Anyone	6-7587	Minimal	Minimal	No	07/16/98	3 yrs.
8Z10-3-32-110-4	Turbulent Convection	J. Doe	6-0988	Low	Minimal	Yes	09/24/98	3 yrs.

Additional fields that may be of value in an activity inventory are the following:

POC Z#

POC Email address

Names of individuals who reviewed the control system

Hazard Identification Tool rating

Type of hazard analysis performed

Name of person authorizing work

Names of persons authorized to do the work

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## 5.0 Hazard Identification

Thorough hazard identification is a critical step in establishing an effective safety envelope for each activity. A useful primer on hazard identification and analysis published by OSHA is available at the following URL address:

<http://www.osha-slc.gov/Publications/osha3071.pdf>.

To assist in hazard identification, the Laboratory has developed two tools described in the section below.

### Hazard Identification Tool

The Hazard Identification Tool is an interactive Web-based tool that is particularly useful for identifying the hazards associated with R&D at the activity level. The tool is available at the following URL address:

<http://hazardid.lanl.gov>

You use the tool by answering 15 nested sets of YES or NO questions. If you answer NO to the highest level question in a set, the more detailed questions will not appear and there is no need to answer them.

Based on your answers to the questions, the tool calculates a "Hazard Rating" of 0, 1, 2, or 3. This rating relates to the potential severity (with 3 highest) of hazards in an operation before quantities, likelihood, or particular circumstances are taken into account. For example, if the operation involves known carcinogens the tool will return a Hazard Rating of at least 2. This means you should consider a "Critical" severity in the risk matrix of the Safe Work Practices LIR 300-00-01. However, if only minute quantities of the carcinogen are being used, the severity might be less.

The tool also provides links to applicable requirements associated with the identified hazards as well as training that may be required. Here too, judgement must be applied to determine whether the requirements and training apply to the actual operation.

For reference all of the questions in the tool are shown below. The tables that are referred to are available through hot links in the WEB version.

1. Are there any accelerators or other radiation generating devices involved in this operation?
  - 1a. Is there an accelerator used in this operation?
  - 1b. Are there any radiation generating devices (RGD) used in this operation?
    - 1b(1). Are radiation generating devices capable of creating a High Radiation Area (>100 mrem per hour at 30 centimeters)?
    - 1b(2). Are there radiation generating devices capable of generating a radiation area?
    - 1b(3). Do the accelerators or radiation generating devices only produce radiation incidental to their primary function (such as electron microscopes, electron beam welders, ion implantation equipment)?
      - 1b(3)i. Does this operation use accelerators or radiation generating devices that are NOT commercially available units which use only inherent shielding as supplied by the manufacturer?
    - 1b(4). Is the radiation generating device an intentional x-ray generating device which produces radiation as part of the primary function (i.e. x-ray diffractometers, x-ray machines)?

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- 1b(4)i. Is the device NOT commercially available?
  - 1b(4)ii. Have any of the radiation generating devices been modified or used outside of the original design specifications?
- 2. In relation to this operation, are radioactive materials (including sealed sources and wastes) generated, handled, processed, used or stored?
  - 2a. Does this operation involve radioactive materials?
  - 2b. Do fissile material (or waste) quantities exceed 500 grams for U-233, Americium, or Plutonium; or 800 grams for U-235;?
  - 2c. Do any of your radioactive materials or radioactive wastes exceed the 'Category 3' hazard threshold values given in the radionuclide table?
  - 2d. Do any of your radioactive materials or radioactive wastes exceed the threshold values given in the radionuclidetable?
  - 2e. Are dispersible radioactive materials being used in this operation?
  - 2f. Will any of your operations involve the transportation of radioactive materials or radioactive wastes?
- 3. Are there any explosives (including explosive waste) handled, processed, used, or stored?
  - 3a. Does this operation involve the transportation of explosives or explosive wastes?
- 4. Does this operation involve the use of lasers ?
  - 4a. Do personnel use, or have the potential to be exposed to class 3b or 4 lasers?
  - 4b. Do personnel perform maintenance on any lasers?
  - 4c. Are any of the lasers NOT commercially available?
  - 4d. For lasers that are commercially available, have any of them been modified from the manufacture's specifications?
  - 4e. Do any of the lasers utilize a beam that is not fully enclosed?
  - 4f. Are laser dyes used in this operation?
- 5. Are chemicals or toxic materials (including wastes) handled, used, stored, or processed in this operation?
  - 5a. Do you have any chemicals or chemical wastes used, stored, or generated that are either known or suspected human carcinogens listed in the Carcinogens Table?
  - 5b. Are there any category 1 chemicals used, stored, or generated in this operation (see Category 1 Chemicals Table)?
  - 5c. Are pyrophoric materials/wastes (of any amount) used, stored, or generated as a part of this operation?
  - 5d. Do you have personnel who work with cyanide or hydroflouric acid?
  - 5e. Does this operation use, store or generate any Organic Peroxides?
  - 5f. For this operation, are toxic or highly toxic gasses, liquids, or solids, stored, used, or generated? (see Toxic Substances Table)
  - 5g. Does this operation use, store, or generate any Class 3 or 4 reactive materials/wastes? (check chemical label or MSDS)
  - 5h. Does this operation use, generate, or store any flammable or combustible liquids or solids?
  - 5i. Does this operation use, generate, or store chemical sensitizers? (See Sensitizers Table)
  - 5j. Does this operation have the potential for skin absorption of toxic chemicals/wastes?
  - 5k. Are multiple chemicals used or mixed together OR are multiple chemical procedures used in the chemical work area?
    - 5k(1). Do you have any processes where chemicals are mixed that will/could create an explosive mixture?
    - 5k(2). Do you have any processes that involve an exothermic chemical reaction (example: polymerization)?
    - 5k(3). Does your operation involve an endothermic chemical reaction (example: pyrolysis)?

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- 5l. Will this operation require the transportation of chemicals?
- 5m. Are caustic/corrosive chemicals/wastes (acids or bases) used, stored, or generated in this operation?
- 5n. Does this operation use, generate, or store chemical reproductive hazards? (See reproductive hazards table)
6. Are workers exposed to any sources of electrical energy (excluding common sources such as wall outlets) or servicing any energized equipment as a result of this operation?
  - 6a. Does this operation include servicing, maintaining, or modifying equip. that requires work on/near exposed energized equip. at: voltage less than 50V, and power less than 1000W or voltage greater than 50V and current less than 5mA AND stored energy less than 10J?
  - 6b. Does this operation include service, maintenance, or modification that requires work on/near exposed energized equip. at: voltage < 50V and power > 1000W OR voltages between 50-250V and current > 5mA, OR voltage > 250V and current < 500mA AND stored energy > 10J?
7. Are there any mechanical hazards (such as motors, pulleys, machinery/shop equipment, forklifts, hoists and cranes, or sources of kinetic or potential mechanical energy) in this operation?
  - 7a. Do workers operate machine shop equipment (such as lathes, mills, band saws, drill presses, grinders, etc.)?
  - 7b. Does this operation involve the use of equipment or machines that could generate kinetic energy such as rotating parts, flywheels, or centrifuges (excluding general shop equipment such as lathes, mills, grinders, etc.)?
  - 7c. Could workers be expected to service or maintain equipment that may contain stored energy such as pneumatic or hydraulic pressure, kinetic energy, chemical sources, etc.?
  - 7d. Will the operation include the use of forklifts and/or motorized handtrucks?
  - 7e. Are overhead cranes/hoists or rigging used in this operation?
8. Could a worker involved with this operation be exposed to non-ionizing electromagnetic radiation or radar systems (excluding lasers)?
  - 8a. Could workers be exposed to RF or microwave energy sources with a power density level greater than 10mw/cm<sup>2</sup>?
  - 8b. Could a worker be exposed to magnetic fields greater than 600 Gauss or Extremely Low Frequency (ELF)?
9. Are there any sources of thermal hazards involved with this operation such as heaters, ovens, steam lines, cryogenic systems, etc.?
  - 9a. Are there any sources of thermal hazards, other than commercially available units or materials such as, soldering irons, hot plates, small qtys. (< .5 gal. ) of cryogenics, etc., that are less than -1° C (30° F) or greater than 54° C (130° F)?
10. Are there any pressure sources to be considered such as gas cylinders, pressure vessels, hydraulic systems, vacuum systems, etc. (excluding house supplied sources) in this operation?
  - 10a. Can this operation result in the worker being exposed to a boiler or pressure vessel?
  - 10b. Can this operation result in workers being exposed to mechanical systems or equipment under stress?
  - 10c. Can this operation result in workers being exposed to hydraulic systems, jacks, actuators, etc. under load?
  - 10d. Can this operation result in workers being exposed to compressed gases, or handle compressed gas cylinders?
  - 10e. Can this operation result in workers being exposed to pressure systems greater than 3000psi?
  - 10f. Can this operation result in workers being exposed to system(s) under vacuum?

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- 10f(1). Could change in pressure create a hazard (i.e. air leak)?
- 10f(2). Could the system implode and potentially injure personnel?
- 11. Are there any sources of excessive noise (i.e. louder than noisy restaurant or very busy traffic) involved in this operation?
  - 11a. Can this operation result in workers being exposed to continuous levels of high noise  $\geq 80$  dBA over an 8-hour time period or impulse or impact noise  $> 140$  dB?
- 12. Are there any additional hazards, not mentioned above, that should be considered such as biological hazards, confined spaces, construction sites, firearms, welding/spark/flame, etc.?
  - 12a. Could a worker be exposed to any biological hazards including handling of human body fluids or tissues (see bloodborne pathogens)?
  - 12b. Does this operation include any confined spaces?
    - 12b(1). Will personnel be required to enter confined spaces?
  - 12c. Could personnel be required to perform their duties from an elevated position (i.e. ladders, scaffolds, manlifts, etc.)?
  - 12d. Do personnel perform functions that involve repetitive motion or other ergonomic concerns?
  - 12e. Will personnel be required to perform their duties in extreme climates or temperatures?
  - 12f. Will welding, cutting, or spark/flame producing operations be conducted in association with this operation?
  - 12g. Are you aware of any other hazardous conditions or potential sources of hazards that may not previously have been addressed by this system that you feel deserve further consideration?
- 13. Does this work involve the use of equipment, tools, or materials outside of their design specifications or outside of the manufacturer's recommendations OR the use of equipment that is NOT commercially available?
- 14. Will this operation be unattended (operating without any personnel in attendance) OR operated with a sole attendant (only one person working alone)?
- 15. Are there any environmental concerns, such as air or wastewater discharges or hazardous or radioactive wastes, or any waste generated in a Radiological Controlled Area in this operation?
  - 15a. Will this operation generate any hazardous wastes, or will personnel be required to handle hazardous wastes?
    - 15a(1). Will any acutely hazardous (P listed) waste be generated (see P Listed Waste Table)?
  - 15b. Will this operation generate any radioactive wastes, or will personnel be required to handle radioactive wastes?
  - 15c. Will this operation generate/store any mixed wastes, or will personnel be required to handle mixed wastes?
  - 15d. Will this operation generate/store any infectious or biohazardous wastes, or will personnel be required to handle either of these wastes?
  - 15e. Will this operation generate administratively controlled waste?
  - 15f. Will this operation generate air emissions or wastewater discharges?
  - 15g. Will ANY waste (radioactive, hazardous, mixed, sanitary, etc.) be produced in a Radiological Controlled Area as a result of this operation?
  - 15h. Have you ever had a NEPA review?

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The Environment, Safety, and Health Identification (ESH-ID) Process is a computer-assisted, web-based, communication and review service designed to assist LANL personnel in identifying and managing Environment, Safety, and Health (ES&H) Laboratory Implementing Requirements (LIRs). It is particularly useful for identifying hazards and potential environmental issues associated with

- new programs, proposals, processes, and/or construction
- decontamination, decommissioning, demolition, or shutdown of a facility
- modification(s) to programs, processes, projects, and/or facilities with the potential to impact the ES&H operating requirements of the facility or the institution.
- Environmental Restoration projects and
- projects involving activities with the potential to
  - 1) generate airborne emissions and/or new waste streams
  - 2) impact water quality
  - 3) impact the ecology of an area or site

The ESH-ID provides for

- project data collection and submission at your desktop,
- computer-assisted review and identification of LANL requirements with the potential to impact your project,
- on-line review and guidance provided by Subject Matter Experts (SMEs) specific to the requirements identified as impacting your project, and
- hard-copy documentation available at your desktop.

Any individual with authority to access internal LANL systems may access the ESH-ID homepage at <http://www.eshid.lanl.gov> and access the ESH-ID on-line system, enter and submit project data. You may also request individual assistance either at the website or by calling the ESH-ID HELP line at 7-2703.

A series of computer screens provides the customer with an opportunity to enter project data almost exclusively in the form of check boxes and/or "Yes," "No," or "Unknown" responses. The data collection instrument is designed to collect data specific to requirements stated in LANL requirement documents. A customized database program then utilizes the data fields to identify those LANL requirements potentially impacting any particular project. Customers are requested to provide data in the following areas:

Programmatic and Project Description  
Purpose, Type, and Scope of Project  
Location, Site, and Facility Data  
Safety and Health Hazards Identification  
Work Environment  
Environmental Factors  
Airborne Emissions  
Waste Management

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The submitted data is checked for completeness, clarity, and compatibility and the computer-assisted review process is implemented to produce a listing of LANL requirements and appropriate SME reviewers. The results of the computer-assisted review are verified and posted to the ESH-ID website. SMEs are automatically notified, visit the website, and provide an on-line review. The results of the ESH-ID review are posted to the ESH-ID Closure website where the customer may enter and track information related to the closure of requirements, issues, and/or concerns identified in the ESH-ID review.

For more detailed information, please access the ESH-ID homepage at <http://www.eshid.lanl.gov>, or call the ESH-ID HELP line at 7-2703.

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## 6.0 Hazard Evaluation/Analysis Techniques

The overall objective of Integrated Safety Management and Safe Work Practices is to effectively control the hazards and prevent the harm they might cause. To achieve this control you must first determine how the harm might occur. Identifying the hazards is only the first step. The second step is to foresee the conditions, circumstances, or manifestations in which the hazard could cause harm. This requires a disciplined “brainstorming” in which potential accident scenarios are imagined and evaluated for their potential risk. The What-If/Checklist technique is a useful methodology for this purpose. Teaming with subject matter experts in its use can be very effective.

Once a set of realistic hazard manifestations has been identified, controls need to be developed to mitigate these hazards and their particular manifestations. To determine whether the residual risk is now acceptable, you must go back and analyze the overall safety of the activity. Frequently, the hazard controls become an integral part of the system design and operation. For example, the choices of materials and system components often have both a safety function and an operational function. The Hazard and Operability Study (HAZOP) and the Failure Modes and Effects Analysis (FMEA) are two of the techniques that are useful for this purpose. Again, teaming with subject matter experts in the use of these techniques can greatly increase their effectiveness.

For activities in which the hazards could potentially pose high or medium initial risk, documentation of the hazard evaluation performed to consider accident scenarios and determine initial risk is required and must be retained. Similarly analyses performed to select or design controls or to determine the effectiveness and reliability of these controls must be retained. These records provide a foundation for modifying or improving the control system and a valuable reference for future users of the controls.

In this section, the What-If/Checklist, HAZOP, and FMEA techniques are described. These can be used separately, in combination, or can be adapted to fill the needs of a specific activity. However, they are most effective when led by an individual trained and experienced in their use.

Other techniques and modifications of these basic approaches can be found in the hazard analysis literature. For many activities, hazard checklists are valuable<sup>1</sup>. The bottom-line is that you need to apply a methodical approach to ensure that you have foreseen potential hazard manifestations and have implemented effective controls to mitigate the risk to an acceptable level.

### What-If/Checklist Technique

The What-If/Checklist technique asks questions about systems and activities to identify hazards and hazardous circumstances. The “what-if” part of this technique, which is a brainstorming session, is followed by a structured review of one or more checklists. When used together, these methods offer a systematic approach for

- identifying equipment failure, human errors, and off-normal conditions;
- determining the potential such events have for creating hazardous circumstances; and
- identifying controls that can eliminate or reduce the consequences of those circumstances.

The What-If/Checklist technique uses a team approach. The team must be made up of individuals who know and understand the specific activities of the proposed work and the basic hazards associated with each activity. The team needs a leader who can keep the brainstorming process moving and the team focused. The team leader must be well prepared to interject questions when the discussion lags.

<sup>1</sup> See for example *Guidelines for Hazard Evaluation Procedures*, Appendix B, Center for Chemical Process Safety, AIChE, New York, 1992, ISBN 0-8169-1091-x.

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## Essential Elements

There are four major phases in the What-If/Checklist technique:

- preliminaries before the team convenes;
- brainstorming to identify hazards;
- checklist review to identify additional hazards; and
- determining causes, consequences, and controls.

## Preliminaries

During the preliminary phase, one or more individuals must

- define the work,
- assemble a team,
- appoint a team leader,
- collect relevant information and supporting documents,
- segment the work, and
- define significant consequences.

## Significant Consequences

Significant consequences (sometimes called consequences of interest) can include impacts to

- worker or public health and safety,
- the environment,
- schedules,
- equipment, or
- public relations.

Establishing significant consequences before you begin to identify and evaluate hazards is most efficient. This allows you to focus your attention on unacceptable circumstances and to recognize when your efforts diverge into nonproductive discussions. Although you establish significant consequences before you begin, you may have to add additional consequences that you identify during the analysis process.

**Note:** Two common mistakes in defining significant consequences are to consider severity but not likelihood and risk with controls already in place.

## Brainstorming

During the brainstorming phase, the team develops “what-if” questions to identify possible events or situations that can cause

a hazardous circumstance, for example, “What if we lose cooling water in the distillation apparatus?” or “What if the valve to the argon exhaust port is closed?” Causes can include equipment or system failures or human behaviors that can result in an event within the defined significant consequences.

Although this technique uses a “what-if” approach, it is also appropriate to ask other questions such as “Is there any way to lose pressure?” or to make statements such as “I think that we could overheat the oven.”

Your team leader or an assigned scribe should capture these open-forum comments on paper for further evaluation during the next phase of the process. The goal of the brainstorming session is to generate as many ideas as possible about what can result in a hazardous circumstance. This is not the time to decide whether an event is likely to occur or to whether any risk is posed by the event. Those decisions will come later.

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## Checklist Review

After the brainstorming phase, your team reviews one or more checklists to ensure that hazards have not been overlooked. If new hazards are identified from the checklists, this may trigger more “what-if” questions.

The use of relevant checklists is what makes this technique more structured and complete than using the what-if format by itself. Your team can use an existing checklist or modify existing ones to suit your particular situation. The team leader is usually responsible for having prepared a checklist prior to conducting the evaluation.

**Note:** Examples of checklists may be found online at [http://eshtraining.lanl.gov/esh13/esh13\\_documents/SWP\\_SUPINFO\\_SS.pdf](http://eshtraining.lanl.gov/esh13/esh13_documents/SWP_SUPINFO_SS.pdf)

## Consequences, Causes, and Controls

After identifying the hazards, your team determines which events are likely and which ones are unlikely to create hazardous circumstances without controls in place. In other words, your team determines whether there are any significant consequences.

If there are significant consequences, your team then identifies credible causes that can create hazardous circumstances. Such causes include equipment or system failures or human behaviors. If there are credible causes, your team then identifies controls that can eliminate the causes or reduce the consequences of the hazardous circumstances. Your team also decides whether the existing controls are adequate and whether additional controls are needed. If the existing controls are inadequate or are nonexistent, your team must make a recommendation on how to control the hazard. The worksheet on the following page is an example of how your team can document the results of your What-if/Checklist study.

## Advantages and Limitations

The advantages and limitations of the What-If/Checklist technique are presented in the following table.

Advantages	Limitations
<ul style="list-style-type: none"><li>• Blends the creative process of brainstorming with the systematic approach of checklists.</li><li>• Checklists help capture most of the known hazards.</li><li>• Preformulated questions speed up the process.</li><li>• Is readily adaptable to different situations and activities.</li></ul>	<ul style="list-style-type: none"><li>• Needs experienced team members to brainstorm effectively.</li><li>• Needs experienced team leader to keep the process moving.</li><li>• Does not create “new” knowledge because it depends on the collective wisdom of the team.</li></ul>

## Suitability

The What-If/Checklist technique is best suited for situations in which specific details of the work or design specifications are not yet established or when the work is not very complex.

The What-If/Checklist technique works best during

- the initial design phase of a project,
- modification to a procedure,
- a short-term project, and a daily prejob briefing or a routine safety meeting.

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## What-If/Checklist Worksheet

Segment: Motorist

Item No.	Events (What-if. . .)	Causes	Consequences	Hazards	Controls	Comments or Action Items
1	motorist spills gasoline on ground?	pressed trigger before placing nozzle in tank overfilled tank drove off while pumping fuel	gasoline could catch fire people could breathe dangerous amount of vapors gasoline could be released to environment people could slip in fuel spill	chemical energy (flammable mixture) toxics (gasoline vapors or liquid)	spill cleanup material sign detailing filling procedure breakaway coupling in pump	recommend no lock on trigger
2	motorist hits pump?	brake failure inattention to detail faulty glasses	see item 1 motorist could be electrocuted motorist could be injured from impact	see item 1 acceleration/ deceleration (unexpected barrier)	post in front of pump elevated pump	
3	motorist neglects to pay?		no safety, health, or environmental consequences			

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## Hazard and Operability Study

The Hazard and Operability Study (HAZOP) technique identifies deviations from an operation or process through the systematic use of guide words. As indicated by its name, HAZOP focuses on the hazards created by deviations from normal operation.

HAZOP studies are based on the assumptions that systems operating under design conditions work well and that problems arise when deviations from design conditions occur. The HAZOP technique starts by defining the parameters of normal operation and then identifies plausible deviations from the design parameters. It then considers the effect that each of these deviations can have on segments of the work, until the entire scope of work is analyzed.

As with the What-If/Checklist, the HAZOP technique uses the team approach of brainstorming to identify hazards. However, in the HAZOP technique, brainstorming is very systematic. The use of guidewords stimulates the team to think of ways in which a process or procedure can fail or be improperly operated.

### 1. Essential Elements

There are three major phases in the HAZOP technique:

- preliminaries before the team convenes;
- determining system deviations; and
- determining causes, consequences, and controls.

#### Preliminaries

During the preliminary phase, one or more individuals must

- define the work,
- assemble a team,
- appoint a team leader,
- collect relevant information and supporting documents,
- segment the work, and
- define significant consequences.

**Note:** Proper segments are crucial to the successful application of the HAZOP technique. If segments are too small, your team will spend much time on redundant scenarios from different segments; if segments are too large, your team may not be able to focus sufficiently on the details to identify important deviations. Your team leader can facilitate the process somewhat by identifying most of the segments before the team meets. However, your team can redefine the segments, if necessary.

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## HAZOP Guide Words

Deviations are identified by combining a guideword with a process condition. The seven guidewords and their meanings are listed in the following table.

Guide Word	Meaning
No (Not, None)	Negation of the design intent
Less (Low, Short)	Quantitative decrease large enough to cause a consequence of interest
More (High, Long)	Quantitative increase large enough to cause a consequence of interest
As well as (Also)	Qualitative increase
Part of	Qualitative decrease
Reverse	Logical opposite
Other than	Complete substitution

## Deviations Using Guide Words

Creating deviations using the HAZOP technique is a repetitive process. Deviations are created by matching the guidewords with as many process variables as your team can identify. For example,

- a “low pressure” deviation is created by combining the guide word “low” with the condition “pressure,” and
- a “loss of power” deviation is created by combining the guide word “no” with the condition “power.”

Any combinations that are physically logical are allowed, such as combining the guide word “reverse” with the condition “procedural step” to create the deviation “an out-of-order action.” Combinations that create illogical deviations, such as “part of temperature” or that are equivalent with other deviations, such as “low temperature,” should not be addressed.

The following table gives some examples of the deviations your team can create with various combinations.

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## HAZOP Deviations

	No, Not, None	Less, Low, Short	More, High, Long	As Well As, Also	Part Of	Reverse	Other Than
<b>Flow</b>	no flow	low rate	high total	misdirection impurities	missing ingredient	back flow	wrong material
<b>Pressure</b>	open to atmosphere	low pressure	high pressure			vacuum	
<b>Temperature</b>	freezing	low temperature	high temperature				
<b>Level</b>	empty	low level	high level	high interface	low interface		
<b>Reaction</b>	no reaction	slow reaction	runaway reaction	side reaction	incomplete reaction	decomposition	wrong reaction
<b>Concentration</b>	none present	too little, too weak	too concentrated	containment	slow mixing	inflow of solvent	addition of other material
<b>Speed</b>	stopped	too slow	too fast		out of synch	backward	
<b>Procedural Step</b>	skipped or missing step			extra actions, shortcuts	actions skipped	out of order, opposite	wrong action
<b>Special</b>	utility failure (power, ventilation, water)	startup, shutdown	loss of containment (leak, spill, rupture)	external activities	maintenance activities	emergency shutdown	

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## Deviations Not Covered by Guide Words

Some general deviations that are not produced through the guideword approach must also be considered. These general deviations include the following:

- leak,
- rupture,
- loss of containment,
- ignition source,
- startup,
- shutdown,
- maintenance,
- testing,
- utility failure,
- adjacent facilities, and
- weather or other external events.

## Causes, Consequences, Controls

The HAZOP technique uses a cyclical, repetitive approach in creating deviations by combining each of the guidewords with as many process variables or procedural steps as can be identified. However, the HAZOP technique is also very sequential.

After choosing a deviation, your team brainstorms to create a list of hazardous conditions that can cause that deviation to occur. If the hazardous conditions are credible, your team determines the likelihood of occurrence and the severity of the harm (that is, the initial risk) should that deviation occur. If the risk is high enough to be a significant consequence, your team proposes controls to eliminate or reduce the impacts of that deviation. Using this sequential and repetitive, approach helps ensure that your team does not miss a significant deviation. However, your team may begin to identify identical hazards and hazardous conditions for different segments. The more experienced your team and team leader are in using the HAZOP technique, the more likely you will be able to recognize ways to re-segment the work to avoid unnecessary and time-consuming repetition.

The following worksheet is an example of how to record the results of your HAZOP study. A complete set of worksheets, based on the different HAZOP deviations may be found online at

[http://eshtraining.lanl.gov/esh13/esh13\\_documents/SWP\\_SUPINFO\\_SS.pdf](http://eshtraining.lanl.gov/esh13/esh13_documents/SWP_SUPINFO_SS.pdf)

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## HAZOP Worksheet

Segment: Underground Storage Tank

Parameter: Level

Item No.	Deviation	Causes of Deviation	Hazards	Consequences	Controls	Comments or Action Items
L.1	empty	same as low level	chemical energy (flammable mixture)	same as low level	confirm total removal of fuel if tank is to be emptied	add to procedure
L.2	low level	normal operations leaks in tank	chemical energy (flammable mixture)	fire or explosion due to ignition of air and fuel mixture	monitor tank level and refill before tank is one-fourth full	no action needed
L.3	high level	backflow of fuel into tank high temperature in tank	toxics (gasoline vapors or liquid) chemical energy (flammable mixture) acceleration/ deceleration (fuel spill)	fuel spill exposure to toxic vapors contamination of soil injury from slipping in fuel	berm and sump around fill and vent pipes automatic fire suppression system spill cleanup material	no action needed
L.4	low interface			no significant consequences		
L.5	high interface			no significant consequences		

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The following flow diagram illustrates the HAZOP process:

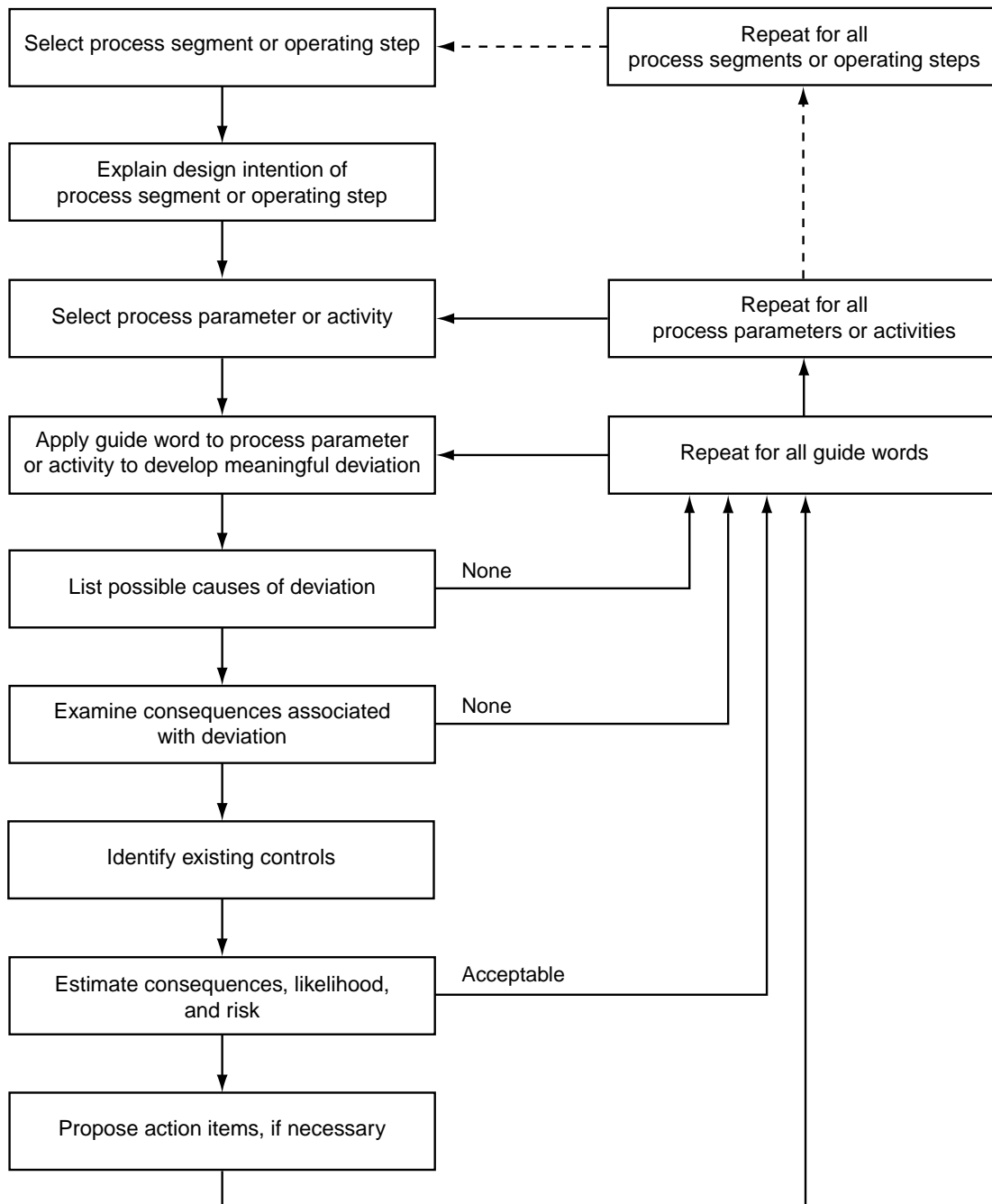


Figure 6.1. HAZOP Flow Diagram

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## Advantages and Limitations

The advantages and limitations of the HAZOP technique are presented in the following table.

Advantages	Limitations
<ul style="list-style-type: none"><li>• Extensively examines consequences of deviations from normal operation or failure to follow procedures.</li><li>• Effectively identifies hazards associated with reactive chemicals or continuous operations.</li><li>• Systematically addresses causes and consequences.</li><li>• Identifies both engineering and administrative controls and the resulting consequences of failure of these controls.</li></ul>	<ul style="list-style-type: none"><li>• Is time consuming.</li><li>• Needs experienced team members to brainstorm effectively.</li><li>• Needs experienced team leader to keep the process moving.</li><li>• Requires well-defined systems or procedures.</li><li>• Focuses on one-event causes of deviations.</li></ul>

## Suitability

HAZOP's focus on operability as designed and its methodical approach are especially useful when analyzing complex systems, when accounting for the human element involved in following procedures, and when identifying the hazards associated with change. HAZOP is the preferred technique of the process chemical industry and most management-of-change programs.

The HAZOP technique works best when

- details of the work and design specifications are well established,
- work activities are well documented,
- replacing or modifying a piece of equipment, and
- changing a process or procedure.

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## Failure Modes and Effects Analysis

FMEA examines the components of a system and how those components can fail. In this technique, the focus is on individual components, rather than on segments of the system as in the HAZOP technique. FMEA first identifies how each component can fail (for example, a valve can fail open or a pressure vent can fail closed) and then determines the consequences should that component fail.

FMEA is a systematic approach that helps ensure that all failure modes for a given component are addressed. This one-event failure technique considers each component independently with no relation to other component failures in the system. FMEA is then systematically applied to each component in the system.

Unlike the What-If/Checklist and HAZOP techniques, FMEA can be done either by a team or by an individual knowledgeable in the process.

## 2. Essential Elements

There are three major phases in the FMEA technique:

- preliminaries;
- defining boundaries; and
- determining failure modes, effects, and controls.

### Preliminaries

During the preliminary phase, one or more individuals must

- define the work, and
- collect relevant information and supporting documents.

### Boundaries

To conduct an FMEA, you first define the boundaries for analysis by doing the following:

- Define the significant consequences before beginning the analysis.
- List and describe each component of the system. Be sure you understand how the component should operate under “normal” conditions.
- Define the boundaries of the system. Treat each boundary point as a component within the system.

### Failure Modes and Effects

In the next phase of FMEA, you determine failure modes, effects, and controls by doing the following:

- Identify as many failure modes as are applicable to a given component. Be sure to define exactly what occurs when the component fails. For example, a valve can stick closed or it can be inadvertently closed by an operator.
- Determine the effects of the component failure on the system. Describe both immediate effects and possible long-term impacts on the system. For example, a seal may leak and have an immediate environmental impact in the local area, but if the material leaked is flammable, then the potential for fire could later impact the building.
- Identify controls. Be sure to consider controls that address both the local effects and the system-wide effects.

The following worksheet is an example of how to document the results of your FMEA.

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## FMEA Worksheet

Component: Underground Storage Tank

Item No.	Identification	Description	Failure Modes	Effects		Hazards	Controls	Comments or Action Items
				Local	System			
1	vessel	underground storage tank	external leak	contamination of environment fire or explosion inside or outside tank	same as local	chemical energy (flammable mixture) toxics (gasoline vapors or liquid)	corrosion grounding	recommend periodic spill sampling around tank
2	same as item 1	same as item 1	external rupture	same as item 1	loss of fuel to pumps	same as item 1	same as item 1	recommend development of emergency procedure for tank rupture
3	same as item 1	same as item 1	plugged tank opening	no flow from tank	same as item 2	same as item 1		recommend level indicator in tank

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## Advantages and Limitations

The advantages and limitations of the FMEA technique are presented in the following table.

Advantages	Limitations
<ul style="list-style-type: none"><li>• Extensively examines consequences of component failures.</li><li>• Effectively identifies hazards associated with mechanical or electrical systems.</li><li>• Systematically addresses causes and consequences.</li><li>• Can generate quantitative results.</li></ul>	<ul style="list-style-type: none"><li>• Is not a repetitive process.</li><li>• Focuses on one-event component failures.</li><li>• Does not readily identify missing-but-necessary components.</li><li>• Does not readily identify operator errors, unless the operator is included as a component.</li><li>• Does not identify hazards associated with reactive materials.</li><li>• May miss hazards that result from system failures outside the defined boundaries.</li></ul>

## Suitability

FMEA's one-event failure approach that considers each component independent of other components in the system can be somewhat limiting. However, because FMEA does address equipment failures, which can be expressed in probabilities, it can generate quantitative results. FMEA works best for finding problems in

- mechanical systems,
- electrical systems,
- alarm systems, and
- safety systems.

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## 7.0 Examples of Risk Determination

The purpose of determining the risk posed by your work is fourfold:

- to provide a guide for the rigor to use in evaluating hazards and developing controls—the higher the level of risk, the more thorough the effort required to evaluate hazards and develop effective controls;
- to determine the rigor of review required for the controls—the higher the level of risk, the more important it is to have other knowledgeable people review the controls;
- to determine the level of management/supervision required to authorize the work—the acceptance of risk is not an individual decision; the higher the level of risk after controls are in place, the higher the level of management required to decide the appropriateness of accepting that risk; and
- to determine the rigor and extent of documentation required.

Risk is a function of the likelihood and potential severity of injury, harm, incurred liability, damage, or loss; for the purpose of this document, a qualitative judgment based on knowledge and experience. In LIR300-00-01 risk is categorized as high, medium, low, and minimal based upon a 4x5 severity-likelihood matrix. The terms in this matrix are intentionally qualitative because the consequences of miscategorization are not major and the benefits of a quantitative risk do not usually justify the costs for this application.

The following terminology is used to describe the potential severity of an accident or hazard manifestation.

**Catastrophic** death, severe injury/occupational illness, severe environmental harm or liability, or severe property damage

**Critical** major injury/ chronic impairment or occupational illness, major environmental harm or liability, or major property damage

**Moderate** minor injury/temporary impairment or occupational illness, minor environmental harm or liability, or minor property damage

**Negligible** less-than-minor injury occupational illness, less-than-minor environmental harm or liability, or less-than-minor property damage

To help calibrate the modifiers, the following guidance and examples may be useful.

For **Catastrophic**, the consequences are characterized as severe. One aspect of severe is lack of full recovery. For example an amputation is an injury from which full recovery is not possible. Similarly, berylliosis is an occupational illness that is disabling and potentially life threatening from which full recovery is not currently achievable. Health threatening contamination of ground water is also severe because the water might not be potable for hundreds or thousands of years. A second aspect is simply the scale of the damage. For example an accident in which a number of people require hospitalization or extended medical treatment could be severe even if they each fully recover. Similarly, an environmental contamination that requires hundreds of thousands or millions of dollars to remediate is severe even if the remediation can be complete.

For **Critical**, the consequences are characterized as major. One aspect of major is extended impairment – months or years before full recovery. Examples might be a back injury that restricts mobility and function of an individual for years. Another example might be burns over a significant area of the body that require months to heal. For contrast, a broken little finger would not be a major injury even if it took 2 months to heal. Major environmental harm might be surface contamination that requires tens of thousands of dollars to remediate. Similarly, major property damage might be loss of tens of thousands of dollars worth of equipment.

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For **Moderate**, the consequences are characterized as minor. A minor injury is one for which medical treatment may be required, but the recovery is rapid (a few days or weeks at most) and complete. An example might be a cut that requires a couple of stitches or the broken little finger. A minor occupational illness might be an allergic reaction that requires medical treatment and dissipates in a few days. A minor environmental incident would include most spills that require involvement of a spill coordinator, but can be cleaned up with hundreds of dollars of effort.

For **Negligible**, the consequences are characterized as less-than-minor. This might be a paper-cut that requires a Band-Aid, but no medical involvement. Another example might be short exposure to a dusty (but non-toxic) environment. A third example might be radiation exposure to levels well below the DOE established exposure limits.

As a rough guide, the terms for likelihood have the following probability of occurring in a particular hazard scenario.

<b>Frequent</b>	10%	or more of the times the activity will be conducted,
<b>Probable</b>	1%	or more of the times the activity will be conducted,
<b>Occasional</b>	0.1%	or more of the times the activity will be conducted,
<b>Improbable</b>	0.01%	or more of the times the activity will be conducted,
<b>Remote</b>	0.001%	or less of the times the activity will be conducted.

In considering likelihood, focus first on achieving acceptable risk each time you conduct the activity and then look at the number of times the activity will be conducted. If the likelihood is stochastic, the total likelihood is equal to the number of opportunities times the likelihood at each opportunity. The best general guidance is to ensure your controls make the risk acceptable at each opportunity and enhance them as is prudent for the number of opportunities or exposures that will be experienced over the duration of the activity. A good example of this principle is managing radiation exposure. First you need to ensure that the dose from a single exposure is completely acceptable. Then, if an individual is going to be exposed repetitively, the controls should be designed to ensure that the cumulative dose is also completely acceptable.

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The following are examples of initial risk determinations for hazards associated with work activities and of accidents and harm resulting from those hazards.

<b>Likelihood</b> <b>Severity</b>	<b>Frequent</b>	<b>Probable</b>	<b>Occasional</b>	<b>Improbable</b>	<b>Remote</b>
<b>Catastrophic</b>		Machining high explosives			
<b>Critical</b>					
<b>Moderate</b>	Handling gamma-emitting radioactive material		Boiling water on hotplate		
<b>Negligible</b>					

<b>Likelihood</b> <b>Severity</b>	<b>Frequent</b>	<b>Probable</b>	<b>Occasional</b>	<b>Improbable</b>	<b>Remote</b>
<b>Catastrophic</b>		High explosives detonate; kill worker and destroy part of building			
<b>Critical</b>					
<b>Moderate</b>	Worker receives excessive radiation dose		Water spills; worker receives second-degree burn		
<b>Negligible</b>					

Figure 7.1. Initial Risk Determinations and Accidents

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The following are examples of residual risk after controls are implemented.

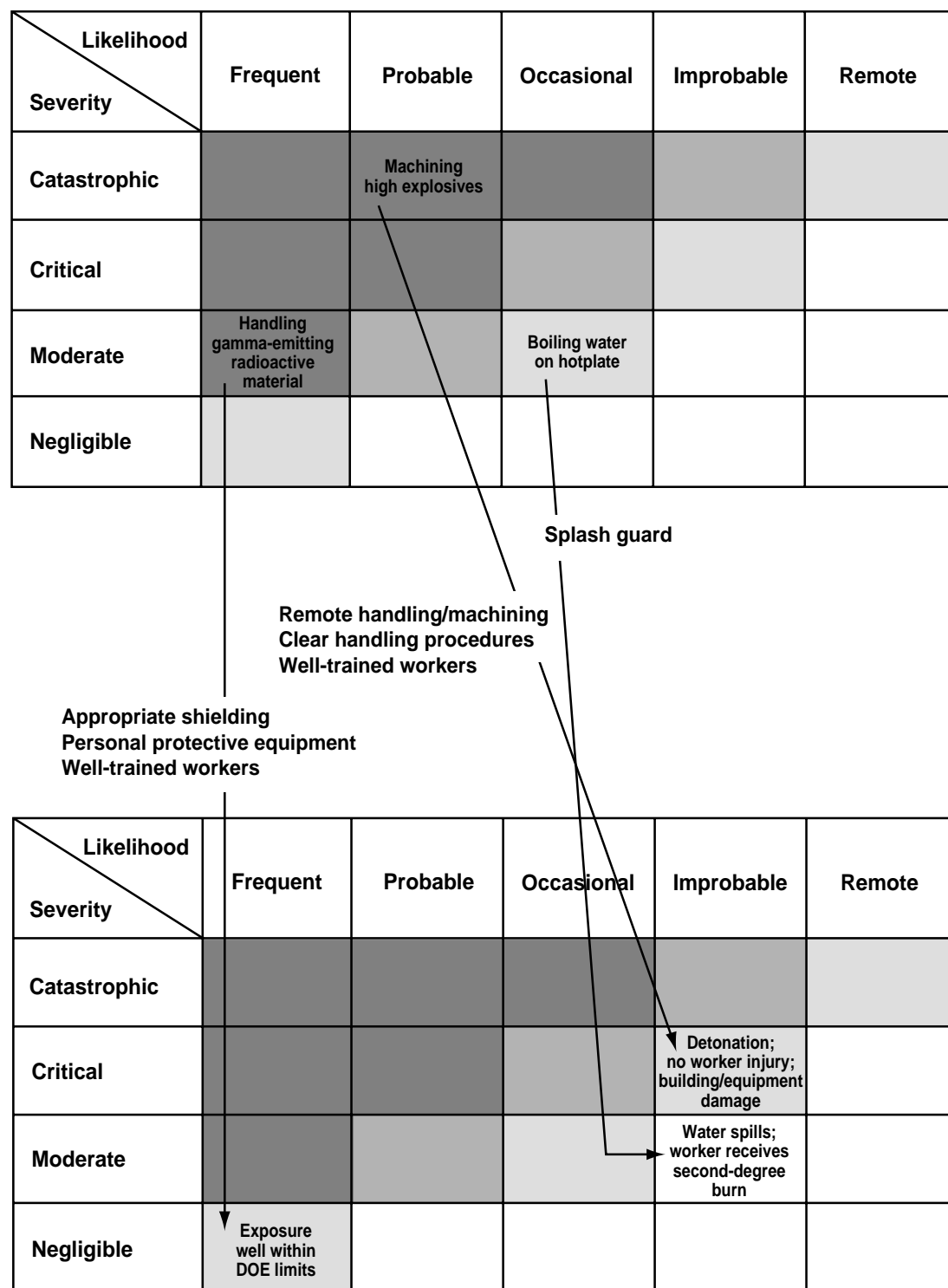


Figure 7.2. Residual Risk Determinations

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## 8.0 Example Hazard Control Plan Cover Sheet

Activity Title

### Selective Electron Beam Etching of Silicon


Activity Identification Number: 00-03-1698-A000-1


#### Author

Name	<u>I. W. Rotethis</u>	<u></u>	<u>4/15/99</u>
Phone	<u>505-555-5555</u>	Signature	Date
Email address	<u><a href="mailto:iwrotethis@lanl.gov">iwrotethis@lanl.gov</a></u>		

Initial Risk Rating: **High**

#### Consultation/Concurrence by

<u>I. K. Nowgases</u>	<u></u>	<u>4/15/99</u>
Name <sup>1</sup> (ES&H Subject Matter Expert)	Signature <sup>2</sup>	Date

<u>C. V. Dexpert</u>	<u></u>	<u>4/15/99</u>
Name <sup>1</sup> (Independent Peer)	Signature <sup>2</sup>	Date


<u></u>	<u></u>	<u></u>
Name <sup>1</sup> (ES&H Subject Matter Expert)	Signature <sup>2</sup>	Date

<u></u>	<u></u>	<u></u>
Name <sup>1</sup> (Independent Peer)	Signature <sup>2</sup>	Date

Residual Risk Rating: **Low**

Work Permits Required none

#### Work Authorized by

<u>I. A. M. Thegroupleader</u>	<u></u>	<u>5/17/99</u>
Name	Signature	Date
<u>Group Leader</u>	<u></u>	<u></u>
Title		

Last Review Date: **5/17/99**  
Review Cycle: **1-year**

<sup>1</sup> indicates consultation on control system

<sup>2</sup> indicates concurrence with control system and residual risk

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## EXAMPLE HAZARD CONTROL PLAN

Activity # 00-03-1698-A000-1

### Selective Electron Beam Etching of Silicon

#### 1. Definition of Work

This experiment is designed to test the potential for controlled reactive etching of silicon crystals with  $\text{Cl}_2$  gas at the focus of an electron beam. To accomplish this, the silicon sample is mounted on a heater platform in the sample chamber of a scanning electron microscope (SEM). Chlorine gas at low pressures is introduced into the chamber and the electron beam is scanned in a pattern on the surface of the silicon. Etch rates are measured by the volume of material etched as a function of sample temperature, beam voltage, beam current, and  $\text{Cl}_2$  pressure.

#### 2. Identification of Hazards

The principal hazards in this activity are:

- |    |            |   |  |
|----|------------|---|--|
| 1. | Toxic gas  | $\text{Cl}_2$ gas   | MSDS available at URL Address<br><a href="http://drambuie.lanl.gov:80/~msds/ohsqform.pl/">http://drambuie.lanl.gov:80/~msds/ohsqform.pl/</a> |
| 2. | Electrical | High voltage on SEM and 115 volt/20 amp on instrumentation  |  |
| 3. | Thermal    | Heater stage provides temperatures up to 500C   |  |
| 4. | Chemical   | Silicon is nontoxic, but can react with other materials such as Al at elevated temperatures to form a eutectic.   |  |
| 5. | Radiation  | The electron beam produces x-radiation. However, at the energies of the beam, this radiation can not penetrate the SEM chamber, and the instrument can not operate unless it is sealed due to OEM vacuum interlocks and filament burnout if not sealed. |  |

#### Risk Evaluation

Based on the toxicity and volume of  $\text{Cl}_2$  gas and the hazardous circumstances identified below:

**Initial Risk – HIGH – requires concurrence of subject matter expert and technical peer.**

The control system described below has been reviewed and concurred with by

I.K. Nowgases – subject matter expert toxic gas handling

C.V. Dexpert – technical peer.

**Residual Risk – LOW – requires Group Leader level authorization**

#### 3. Hazard Control

##### Task A – Sample Mounting/Demounting

In this task the sample is attached to the heater block with screw hold-downs and mated to the bayonet heater mount in the sample chamber. The heater leads with 5 volt, 10-amp current capacity are connected to the heater. Demounting the sample is the reverse of the mounting process.

Hazard	Hazard Scenario	Hazard Controls
Thermal – up to 500C	Contact with hot heater stage	WAIT AT LEAST 30 MINUTES for heater stage to cool before touching it.

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## Task B – Silicon Etching with Chlorine

In this task  $\text{Cl}_2$  gas is introduced into the sample chamber and the electron beam is focused on the silicon surface to activate etching. The engineering controls are described in the table below and are illustrated in the diagram below.

Hazard	Hazard Scenario	Hazard Controls
Toxic $\text{Cl}_2$ gas  See applicable institutional req. list at end	General hazard communication	Post Hazardous Gas sign on Laboratory Door Acquaint all workers with $\text{Cl}_2$ gas MSDS
	Potential major release of $\text{Cl}_2$ gas due to failure/rupture of plumbing system	Use lecture-size bottle of $\text{Cl}_2$ gas (0.5 liter, 1000 psi) to minimize total volume of toxic gas that could escape. Mount $\text{Cl}_2$ gas bottle in hood. Use with sash at set point. Secure $\text{Cl}_2$ gas bottle to hood wall with dedicated bracket
	Potential release of $\text{Cl}_2$ gas due to corrosion of regulator or other components	Use stainless steel tubing and Swagelok fittings for all $\text{Cl}_2$ gas plumbing and connections Use $\text{Cl}_2$ gas approved regulator – Matheson 3330 Purge regulator and plumbing system with dry nitrogen after each use.
	Potential release of $\text{Cl}_2$ gas due to improper operation (e.g. opening needle valve with sample chamber open)	Use flow regulator with max flow of 10 cc/min in series with $\text{Cl}_2$ gas regulator (see diagram below) Maintain line pressure to SEM <5 psi Follow operating procedure described below.
	Potential release of $\text{Cl}_2$ gas by back-flow through the purge system	DO NOT connect the purge system to “house” air or nitrogen system. Use independent dry nitrogen cylinder as purge gas source Install one-way valve in purge line to prevent back-flow and contamination of purge cylinder with $\text{Cl}_2$ gas
	Potential release of $\text{Cl}_2$ gas from pump exhaust	Route pump exhaust through $\text{Cl}_2$ gas scrubber mounted in hood.
	Electrical – High Voltage	DO NOT open or modify high voltage power supply on SEM. If maintenance is required, contact qualified factory repair service.
		SEM is designed with interlocks on the high voltage system. These interlocks disable high voltage unless system is closed and under vacuum. If you suspect failure of the interlock system, contact qualified factory repair service.
		Refer to SEM operation manual (attached to SEM) for filament changes or other user maintenance.
Electrical – 115 V/ 20 amp	Contact with 115 V/ 20 amp power that operates SEM controls/instruments	DO NOT open or modify electrical system. If maintenance is required, contact qualified factory repair service.

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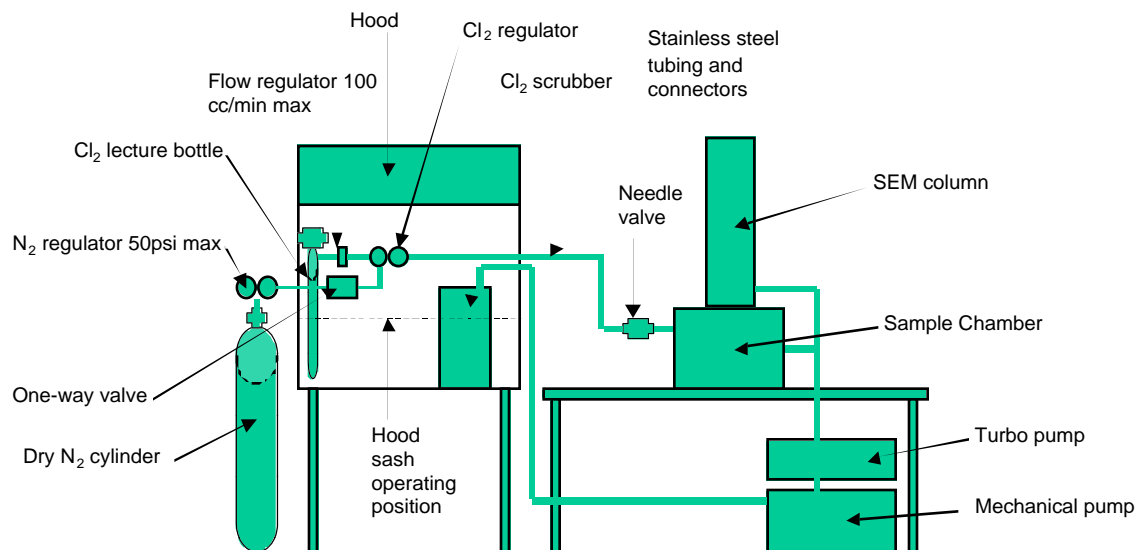


Fig. 8.1 Schematic of experimental setup

## Training Requirements

All workers involved with this operation must have:

1. Gas Cylinder Safety – LANL Course (9518)
2. Pressure Safety Orientation LANL Course (769)
3. Waste Generation Overview LANL Course (8477)
4. On the job training by activity POC to include the following:
  - a. general hazard review including Cl<sub>2</sub> gas toxicity
  - b. walkthrough of hazard controls
  - c. walkthrough of operating procedures
  - d. checkout of knowledge and use of controls
  - e. checkout of operating procedures

## Applicable Institutional Requirements

LIR 402-100-01.0 Signs, Labels, and Tags

<http://labreq.lanl.gov:1800/hdir/labreq.html/>

Select LIRs under Operations Requirements/Guidance

AR 6-9 Safe Handling of Hazardous Gasses (May 3, 1991)

<http://labreq.lanl.gov:1800/hdir/labreq.html/>

Select Master Index by Document Number

AR 14-1 Pressure Systems Including Compressed Gas Systems

<http://labreq.lanl.gov:1800/hdir/labreq.html/>

Select Master Index by Document Number

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## 4. Perform Work Safely

### Readiness Checks and Operating Procedures

**Before each day's etching operation do the following:**

1. check to ensure hood is operating properly
2. visually inspect plumbing system
3. check that needle valve is fully closed
4. check that  $\text{Cl}_2$  gas regulator second stage is set for 0 psi (i.e. fully counter clockwise)
5. open  $\text{Cl}_2$  gas main cylinder valve (one half turn is sufficient)
6. set regulator to 5 psi or less

### Sample exchange and experimental operation

1. mount sample in SEM and pump down
2. heat sample to desired temperature
3. open needle valve to SEM chamber
4. pump at ~10 cc/min for 5 minutes
5. throttle pump to SEM chamber
6. set needle valve to achieve desired  $\text{Cl}_2$  gas pressure.
7. etch with electron beam for desired duration
8. CLOSE NEEDLE VALVE
9. open throttle valve and pump for ~ 5 min.
10. allow sample to cool for ~30 minutes
11. use standard SEM shut down and remove sample

**At the end of daily operations do the following:**

1. close the  $\text{Cl}_2$  gas main cylinder valve
2. open SEM pump throttle valve
3. open nitrogen purge cylinder main valve
4. set nitrogen purge regulator for 10 psi
5. open needle valve to SEM chamber
6. pump at ~10 cc/min for 10 minutes
7. close needle valve
8. close nitrogen purge cylinder main valve
9. shut down SEM.

### Waste Management

The primary waste from this experiment comes from the  $\text{Cl}_2$  gas scrubber. The sodium hypochlorite solution must be replaced when the PH drops below 9. The waste solution is transferred to the dedicated 5-gallon container for sodium hypochlorite in the satellite waste storage area. Use the procedure for chemical solution transfer (00-03-1698-A000-4) for this operation. This storage area is in the cabinet under the hood. When the container is approximately 3/4 full, contact the Division Waste Coordinator at 5-5555 or 104-5555 for disposal. When the pressure in the  $\text{Cl}_2$  gas cylinder or the  $\text{N}_2$  gas cylinder drops below 100 psi, return the cylinder to the Gas Plant for refilling or replacement.

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## Emergency Procedures

1. If a major Cl<sub>2</sub> gas leak occurs, evacuate the room immediately. Close the door. Call 911 and report emergency. Evacuate the building using PA system in the Group Office.
2. If a minor Cl<sub>2</sub> gas leak occurs (i.e. slight smell of Cl<sub>2</sub> gas), close the Cl<sub>2</sub> gas main cylinder valve. Leave the room and close the door. Allow room to exhaust for 30 minutes. Leak check system to isolate and solve problem before restart.
3. If unusual or unexpected operation is observed, stop work. Close the Cl<sub>2</sub> gas main cylinder valve. Put system in safe condition. Diagnose and solve the problem before restarting.
4. For other emergencies, such as fire in building, close the Cl<sub>2</sub> gas main cylinder valve. Follow normal emergency procedures.

## 5. Review and Improvement

The review cycle for this Hazard Control Plan is 1 year. At this time the system will be evaluated for changes in the work scope, hazards, or other conditions that warrant revision of the hazard-control system. Any significant modifications that impact the safety envelope for the activity prior to that time require updating this Hazard Control Plan and reauthorization.

Change control is accomplished by retaining the master Hazard Control Plan document on the Division ES&H server. The current version can always be viewed via the web at the following address:

<http://www.lanl.gov/Division/ES&H/HCPs>

When changes in the Hazard Control Plan are made, the authorized workers will be notified by email. It is their responsibility to understand the changes and to destroy any paper copies of the previous Hazard Control Plan.

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## 9.0 Suggested Template Hazard Control Plan

In this section on the following pages is a suggested template for a Hazard Control Plan. It is based on the example of the previous section. To obtain a copy of this template, use the following URL address:

<http://labreq.lanl.gov/pdfs/ops/eshform/LIGt3000001.doc>

The template is structured such that text needs to be substituted, at a minimum, for lines that are in ALL CAPS. Refer to the previous example to see how these substitutions might be made.

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## HAZARD CONTROL PLAN

Activity #      INSERT ACTIVITY # HERE

**INSERT TITLE HERE**

### 1. Definition of Work

INSERT A SHORT DESCRIPTION OF THE WORK. (1 TO 2 PARAGRAPHS ARE USUALLY SUFFICIENT.)

### 2. Identification of Hazards

The hazards associated with this activity are:

1. INSERT HAZARD (E.G. TOXIC CHEMICAL – CHLORINE GAS)
2. INSERT HAZARD (E.G. ELECTRICAL – 1000V, 1 A)
- 3.

### Risk Evaluation

Based on SPECIFY METHOD USED TO DETERMINE INITIAL RISK

**Initial Risk** – (SELECT **HIGH, MEDIUM, LOW, OR MINIMAL** BASED ON HAZARD EVALUATION)

The control system described below has been reviewed and concurred with by

INSERT NAME – subject matter expert in INSERT AREA OF EXPERTISE

INSERT NAME – subject matter expert in INSERT AREA OF EXPERTISE

INSERT NAME – independent peer in INSERT AREA OF EXPERTISE

INSERT NAME – independent peer in INSERT AREA OF EXPERTISE

**Residual Risk** – – (SELECT **MEDIUM, LOW, OR MINIMAL** BASED ON CONTROL SYSTEM EFFECTIVENESS AND CONSULTATION/CONCURRENCE OF THE SUBJECT MATTER EXPERT/INDEPENDENT PEERS AS REQUIRED)

### 3. Hazard Control

#### Task A – INSERT TASK NAME HERE

INSERT A SHORT DESCRIPTION OF THE TASK. (A FEW SENTENCES ARE USUALLY SUFFICIENT.)

Hazard	Hazard Scenario	Hazard Controls
IDENTIFY HAZARD	DESCRIBE THE HAZARD SCENARIO OR CIRCUMSTANCE OF EXPOSURE	DESCRIBE THE CONTROL ESTABLISHED TO MITIGATE THIS HAZARD SCENARIO AND HOW IT SHOULD BE USED

### Comments

INSERT ANY COMMENTS NEEDED TO ENSURE UNDERSTANDING OF THE HAZARDS AND CONTROLS HERE

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## Task B – INSERT TASK NAME HERE

INSERT A SHORT DESCRIPTION OF THE TASK. (A FEW SENTENCES ARE USUALLY SUFFICIENT.)

Hazard	Hazard Scenario	Hazard Controls
IDENTIFY HAZARD	DESCRIBE THE HAZARD SCENARIO OR CIRCUMSTANCE OF EXPOSURE	DESCRIBE THE CONTROL ESTABLISHED TO MITIGATE THIS HAZARD SCENARIO AND HOW IT SHOULD BE USED

## Comments

INSERT ANY COMMENTS NEEDED TO ENSURE UNDERSTANDING OF THE HAZARDS AND CONTROLS HERE

## Task C – COPY BLOCKS ABOVE AND ADD AS NEEDED

INSERT DIAGRAM OR FIGURES HERE IF NEEDED TO UNDERSTAND HAZARDS AND CONTROLS

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## **Training Requirements**

All workers involved with this operation must have completed the following

### **Laboratory Training:**

- a. LIST LANL COURSE HERE
- b.
- c.

All workers involved with this operation must have completed the following

### **On-the-Job Training:**

- a. DESCRIBE ON-THE-JOB TRAINING REQUIREMENT
- b.
- c.

## **Applicable Institutional Requirements**

LIST APPLICABLE LABORATORY LIR'S OR OTHER REQUIREMENTS  
(PROVIDE A URL ADDRESS TO THESE DOCUMENTS )

## **4. Perform Work Safely**

### **Readiness Checks and Operating Procedures**

**Before each day's etching operation do the following:**

1. LIST ITEMS FOR DAILY READINESS CHECK
- 2.
- 3.
- 4.

**In operation, follow the following procedure**

1. LIST STEPS IN ANY PROCEDURES THAT ARE NEEDED
- 2.
- 3.
- 4.
- 5.
- 6.
- 7.

**At the end of daily operations do the following:**

1. LIST STEPS IN ANY SHUT DOWN PROCEDURES THAT ARE NEEDED
- 2.
- 3.
- 4.
- 5.

## **Waste Management**

IDENTIFY ANY WASTES THAT ARE GENERATED IN THE ACTIVITY AND DESCRIBE HOW THEY ARE TO BE HANDLED.

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## **Emergency Procedures**

1. LIST ANY EMERGENCY ACTIONS/PROCEDURES THAT ARE RELEVANT TO THE ACTIVITY.
- 2.

## **5. Review and Improvement**

The review cycle for this Hazard Control Plan is

IDENTIFY REVIEW PERIOD HERE

At this time the system will be evaluated for changes in the work scope, hazards, or other conditions that warrant revision of the hazard-control system. Any significant modifications that impact the safety envelope for the activity prior to that time require updating this Hazard Control Plan and reauthorization.

Change control is accomplished by

IDENTIFY CHANGE CONTROL STEPS/PROCESS HERE

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